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THE COALING OF WARSHIPS.

BY LIEUTENANT COMMANDER J. R. EDWARDS, U. S. NAVY.

"Coaling ship" is now regarded as an important *evolution* by flag and commanding officers, and as a result of the personal interest taken in this drill by those directing our fleets and squadrons, there must of necessity be a progressive improvement in the manner and time of carrying on the work.

The general order issued upon this subject by the Navy Department making the evolution applicable to all hands has been received with exceptional favor on board the cruising vessels. Heretofore a portion of the crew has been excused from this exercise, while some of the officers may have found it a convenient season to secure leave of absence and remain from the vessel until the coaling was finished.

Now, that everyone attached to a warship, including the commanding officer, will share in the discomfort of coaling, and therefore have a personal interest in making the task a less unpleasant one, may it not be expected, that any plan or sug-

gestion for shortening the time or lessening the evil will receive a little more consideration than has been accorded heretofore?

Although our Navy ranks fourth in relative size, yet it is probable that no other service is more familiar, at least, with the discomfort of coaling. During the past ten years our ships have been very actively employed, and there are but few of them which have not made long cruises. In several parts of the world I have been told by dealers, that our warships insist upon close filling, and that their trimmers always object to such stowing of bunkers. It is probable that other nations, by reason of having coaling stations, do not find it necessary for their warships to make so many long journeys, and thus the necessity for completely filling bunkers may not exist with them. For this and other reasons I believe that we now know as much about the evil and demoralization attending coaling as any one else.

As a result of the Department's order to make coaling an *evolution*, there has already been created a friendly but spirited rivalry between vessels of the same class. The relative worth of buckets, bags and baskets, for handling coal has been more carefully inquired into. To create competition between the different divisions on board ship, additional hoisting gear has been planned and other conveniences suggested. Care and ingenuity has also been exercised by the subordinate officers to devise means whereby their divisions would exhibit zeal and interest in the work.

So far as the ship's companies are concerned, all improvements must in great part be limited to increasing the amount taken out of the collier or barge. A gain there is of course beneficial, but it is at the bunkers where the real evil lies, and in that direction improvements of an important character must be made.

BLOCKADES AT BUNKER OPENINGS.

Whenever the bunkers are to be filled, it is safe to say that coal will be supplied to the bunkers more rapidly than the firemen can trim it. Blockades are sure to occur, and these delays are liable to happen, not only at the end of the coaling, but on some vessels from almost the beginning of the work. Either

damp or lump coal will soon block most inclined chutes, so, whenever the coaling trunk is other than vertical, the clearing of the chutes will often commence with the coaling of the bunkers. As an illustration of how sluggishly coal moves, I was told by a commanding officer that during one coaling of his vessel, anthracite coal would not run down a wooden chute that was inclined at an angle of 30 degrees. If a block would occur at this angle with anthracite coal, one can appreciate how quickly bituminous coal would stop running down a chute inclined at an angle of 45 degrees.

The question of coaling warships is, therefore, in great part the question of rapidly and completely stowing the bunkers, for any improvement in that direction will make the entire work easier. A blockade in coaling causes demoralization, for it means, particularly to the crew, prolonged discomfort and irritation.

CHANGES IN BUNKER ARRANGEMENTS NECESSARY.

The efficiency of our warships, therefore, demands that a change be made in the design of bunker arrangements whereby delay need not ensue in the trimming of the coal. There is no reason why sufficient bunker openings should not be available to make it an easier matter than heretofore to fill these compartments. There need be no weakening of the vessel by cutting such openings, for if a stiffening ring can make up in strength for an opening in a boiler which is subjected to a pressure of 160 pounds per square inch, surely an angle frame or stiffening ring can be fitted which will make up for the loss of strength due to cutting a hole in a compartment whose walls are not subjected to severe strain.

TOO FEW RATHER THAN TOO MANY OPENINGS EXIST.

The trouble with our warships is that too few openings have been cut rather than too many. On board some vessels there are no cargo ports for the torpedoes, and now the machine has to be taken apart to be carried below. On another vessel there is only one ladder for reaching the redoubt and turrets, and

numerous other illustrations might be given where further openings are not only desirable but necessary.

The more one goes to sea in a war vessel the more impressed he is with the fact that better communication must be established between the various compartments, and therefore the insufficiency rather than the excess of openings becomes apparent. The individuals most interested in keeping the watertight appliances in efficient condition are those whose work is in great part beneath the protective deck, for they will know that any neglect on their part may cost them their lives, and if these men ask for more openings to the bunkers, there must be reason for the request.

TRANSVERSE BUNKERS DESIRABLE BUT DIFFICULT TO OBTAIN.

It has been suggested that the bunker question can be solved by building transverse compartments. This seems a simple method of improving matters, but it is hardly possible to build bunkers in the manner proposed. From an engineering standpoint transverse bunkers are very desirable, for they would not only be large and easily stowed, but coal could be taken from them very rapidly and quickly in times of emergency. Seldom, however, does the naval architect provide transverse bunkers, for on board a warship the space alloted the boilers and machinery is always limited, particularly in the direction of length. On large and comparatively low-powered vessels room for transverse bunkers might be secured. But the modern battleship has to carry armor and other special weights which passenger and freight steamers are not hampered with. Magazines for powder and shell must also be provided for, and so beneath a protective deck there are urgent demands for space from many quarters. From its character and construction the war vessel must, therefore, be made shorter than merchant craft, and thus the arrangement of transverse bunkers is difficult to secure. No one who has anything to do with a modern battleship would care to sacrifice fore-and-aft bunkers for transverse ones, for, independent of the fact that the bunkers are a protection from

ramming as well as from shell, the fore-and-aft bunker walls contribute to the structural strength of a vessel.

HOW OUR COAL BUNKERS HAVE BEEN DESIGNED.

One has only to make a hurried inspection of our coal bunker arrangements to discover how faulty they are. This is the way some have been planned, as told by a naval officer in discussing an article upon the coaling question: (Vol. I, "Transactions of the Society of Naval Architects and Marine Engineers.")

"You see, in designing our ships in the beginning of the reconstruction of the Navy we have had a good many serious problems to work out, and, naturally, we have devoted ourselves to those first, and have been content to put the coal in any space that happened to be left."

In disscussing this same paper another officer says:

"The only satisfaction, I think, we can find in the progress that we have made in the facilities for coaling, stowing and delivering coal is that we have done as well as other people, though that is very little."

With such admissions is it surprising that an immediate change is demanded by our commanders and those who serve under them at sea? Those who have to endure the discomfort and dangers attending existing arrangements are surely justified in demanding that radical improvements be made.

If it is true that oftentimes we derive a mild satisfaction from the misfortunes of our friends, then some may find a little comfort in the fact that mistakes have been made in bunker construction by other nations. This is told of one of the British warships:

"In the *Blenheim* there are some curious arrangements still which will hardly be repeated. In this cruiser, if it is desired to take fuel from the bunkers above the armor deck, it has to be shoveled out into the passage which is also used for supplying ammunition. One has only to pay a visit to these wing passages to realize what a mess there would be if it became necessary to draw coal from the upper bunkers while a fight was in progress. It is safe to say that either the speed of the ship or the speed of the firing would suffer."

COAL BUNKERS NOT HOLDS OF VESSELS.

It is remarkable, that many people who ought to know better look upon the bunkers of warships as something but little different from the holds of merchant vessels. They seem to regard these compartments as deep pits into which the coal has simply to be dumped. To show the difference, in the case of the British collier *Iona*, 2,000 tons of coal were put into *one* hold without trimmers going down at all. The cruiser *San Francisco*, with a coal capacity of 628 tons has fifty-two bunkers, an average of about twelve tons each. With small bunkers of this description stowing commences very shortly after coaling begins. In the merchant service there is practically no trimming to be done, otherwise coal could not be handled with the rapidity that is now secured. There must be very large hatches in such ships. Handling coal for the merchant marine has now been developed to such a degree that giant mechanical marvels are able in the space of a minute to pick up a loaded car, overturn it, empty the contents in the hold of a vessel, and return the car to the railroad track. These performances of merchant ships are remarkable, but they have no relation to coaling the bunker of a warship, although there are persons who will quote some such record when annoyed by being told that some chute leading to a small bunker on a gunboat has been quickly choked.

SMALL BUNKERS ALSO DIFFICULT TO EMPTY.

Whenever the design of bunker arrangement makes it difficult to stow these compartments, it is almost a certainty that trouble is had in emptying them, not because there is any direct relation between stowing bunkers and supplying furnaces, but by reason of the fact that if but little attention has been given to designing arrangements which will permit the bunkers to be readily stowed, it is reasonable to presume that not much more consideration has been given to the question of emptying these compartments.

Another disadvantage of bunkers that are difficult to stow is in the fact that at times they are likely to be insufficiently filled, and therefore a shortage of fuel may sometimes occur. Where there are fifty bunkers to be filled, it is simply impossible for the few

engineer officers always to personally look out for their stowing, and so one need not be surprised if a war vessel is occasionally imperiled by failure to trim the bunkers properly. After continuous steaming there will be the heaviest coaling, and at such times it is likely that important repairs will have to be carried on which will require the personal supervision of the engineer officers. Upon such occasions, either the supervision of the coaling or the direction of the repairs will have to be entrusted to subordinates. Then why not arrange the bunkers so that the coaling could not only be quickly done, but there could be little liability of a shortage occurring from improper stowing. Where small pocket bunkers exist over boilers, particular care should be taken in providing several openings, for otherwise it will be a difficult matter to keep the trimmers in these bunkers, since the work is too distressing for any one to remain there except for a brief period.

FEWER BUNKERS BUT MORE DECK OPENINGS REQUIRED.

The arrangements of bunkers can be improved by reducing their number. There are too many compartments in which the coal is carried, and this has been due in some cases to the effort to preserve the sacredness of the protective deck. Much of that sacredness should be brushed away, for with the improvement in modern ordnance there can be very little protective feature in a deck that is often less than three inches thick. More openings at least should be cut in this deck for transferring coal from the upper to the lower bunkers. The structural strength of the vessel can hardly be assailed by fitting swinging doors to permit rapid coaling, for strengthening frames can make up for any such cutting.

No bunker should be built which has not at least two openings, for it can hardly be deemed a necessity to direct any man to stow a bunker while coal is being emptied into the only opening.

STOWING BUNKERS VERY EXHAUSTING WORK.

At times the trimming of coal in the bunkers of a war ship is a frightful task, and there is not a chief engineer in any navy who has not often been saddened at the sight of his men emerg-

ing from the bunkers almost in a state of collapse. If the exact condition of affairs could be presented to our naval administrators, then no ship would be permitted to go to sea until every possible improvement had been effected in her bunker arrangements that the structural design of the vessel would permit. On one of the blockading vessels off Havana, some of the bunker holes were 20 feet apart, and one can well believe that close trimming would be almost an impossibility in such bunkers.

When coaling the mercantile marine in many ports, the trimmers receive double the pay that is given those carrying the coal to the bunkers. These trimmers do not stow nearly as closely as the firemen and the coal passers on the war vessel, for I have been repeatedly told that it was impossible for the contractors to make their trimmers stow in this manner. And it was also told me, either at Aden or Port Said, that one of the merchants would not contract for coaling the Japanese battleship *Itsukishima*, because trimmers could not be secured who would fill her bunkers, since these compartments were so numerous and contracted that the work of stowing them was particularly exhausting.

The following brief excerpt from a British publication may tell something of the character of the work of coaling warships:

"Down in the collier's hold, the blue-jackets filling bags as fast as they can, break forth, now and again, into bursts of song, which are drowned when the rattling winch hoists a bunch of coal bags into mid air.

"But the weird moving picture going on beneath the yard-arm is only the fun and frolic of coaling. The coal that these merry demons pour so generously down the circular openings into the bunkers is not finished with, as one might imagine. Every bunker harbors three or four coal trimmers.

"Of all the stoker's duties, this is one of the heaviest. Every bunker has to be packed, and that as quickly as the coal can be poured down; and when a bunker opening gets choked, they don't ask anxiously on deck, 'Have we buried the coal trimmers?' They blame them for not stowing it fast enough. As a bunker gets filled the trimmers have to come up, till the last

man left has to lie flat on his back pushing the coal up into the corners with his feet. As they emerge from their holds in the intensity of their blackness the deck hands only look grey by comparison."

Much of this kind of work can be obviated, for on some of the ships an half dozen additional bunker plates would greatly mitigate existing conditions. Is it too much to expect that enough openings should be provided whereby a portion of the engineer's division in times of emergency could assist the deck force in unloading the collier and trucking the bags to the bunker openings?

SLIDING DOORS BETWEEN BUNKERS.

Except where they lead directly to the fire room there should be no vertical sliding doors connected with the bunkers. I have never seen a transverse sliding door *between bunkers* that could ever be completely opened under a quarter of an hour, when coal was on either side of the door and had been there for some time. After the vessel has met heavy weather the weight of the coal causes the supporting bulkhead to spring, so the door jambs on the sliding surface. It is an easy matter when everything has just been overhauled, when the elevating gear is free of coal dust, and when the sliding surfaces are slushed, for the doors to be worked, but these are not seagoing conditions. It is always under some favorable circumstances, however, that the navy yard authorities operate the doors. At sea, when it is attempted to work one of these doors it is often a question of hours before it can be either opened or closed, for this is due to the fact that, through changes of temperature, the connecting rods expand or contract, the bevel gears bind and the supporting brackets carry away. It may be urged that these sliding doors between the coal compartments are only fitted where the bunkers are quite narrow. But surely this does not justify the use of an unreliable contrivance which impairs the integrity of the watertight compartment system. The vertical sliding door, however, is not a necessity, for a double-acting hinge can be fitted to a swinging door which will not only permit the full opening to be secured,

but which will not interfere in the slightest with the trolleying of the coal. Since there is a general order in existence to keep the bunkers filled, months often elapse before some of the sliding doors can be operated, and it is during those intervals that the rusting of the surfaces occur. It is very easy to construct sliding doors which will cut through wooden boxes, folded paper, and operate through coal, either by hydraulic or electric means, so long as the tests are carried under conditions dominated by the inventor, or the tests are made by those who have installed the arrangement. Such a test undoubtedly may be satisfactorily carried on before the vessel has gone to sea, but all favorable conditions are changed when the ship has been subjected to strain in a seaway.

DANGER OF AMIDSHIP LONGITUDINAL BULKHEADS IN BUNKERS.

Except for some special reason, there should be no amidship longitudinal bulkheads in the bunkers. If it is necessary to strengthen the vessel by continuing the stringers to the frames, then these bulkheads should have lightening holes in them, or be fitted with some absolutely reliable contrivance whereby water entering on one side of this bulkhead could flow freely to the other side.

This would prevent any sudden and heavy listing of the ship. Any excessive listing would expose the plates below the armor in time of battle, thus even permitting the shell from the enemy's secondary battery to reach the thin plates.

I have been informed by an officer who served on board the *Charleston* that the ship was at one time placed in a perilous position by the flushing pipe leaking in one of the large upper bunker compartments, one side of which was an amidship longitudinal bulkhead.

It would seem that a ship was rather structurally weak where there was a necessity to construct such a bulkhead for stiffening purposes.

COALING TRUNKS WITHIN BUNKERS OFTEN UNNECESSARY.

As far as possible coaling trunks should be removed from the upper bunkers, for there is no reason why the lower compart-

ments should not be filled from the upper ones. This could be readily done by having a sufficient number of swinging doors fitted in the protective deck. These trunks are seldom of benefit, for they are not only liable to be choked up, but it is not possible to use them at the same time for filling the upper and lower bunkers. In shifting coal from the upper to the lower bunkers they are a serious inconvenience if not a menace, since the passages to the lower bunkers are through these trunks. By reason of this inconvenient opening, the time and labor of emptying the upper bunkers is manifoldly increased. The trunks should be removed, if for no other purpose than to obviate the use within them of the circular battle plates for preserving the watertight features of the protective deck. The excessive weight of this plate, the contracted space for fitting the plate into position, and the difficulty of setting up on the strong back, all make it impossible for any one in a reasonable time to operate this mechanical appliance for the safety of the vessel. As there is no room within the trunks to stow the battle plates and strong backs without interfering with the firemen and coal trimmers, the contrivance is more of a detriment than a benefit. Wherever there is a watertight plate in the protective deck, it should be hinged, for any contrivance consisting of loose parts is sure to be inefficient, due to the difficulty of keeping the separate portions together.

MORE OPENINGS BETWEEN UPPER AND LOWER BUNKERS.

The swinging doors which it is proposed to fit in the protective deck should be so constructed that as far as possible they would be flush with the upper side of the structure. Such doors have already been fitted in many ships, but there are too few of them. Some of these doors should open upward, but most downward, and dogs could be used to lock them where necessary. When the lower bunkers are partly empty it would then only be necessary to unlock one of the doors opening below to commence lowering weights, and by such means the upper bunkers could be cleared of coal in a fraction of time that it now takes to shovel it through an opening in the trunk. These doors should be of rectangular shape with rounded corners. An

angle frame could be riveted to the deck, and its rivets would have countersunk heads so as not to project above the plates. Where the decks are of sufficient thickness the leaf of the hinge could be recessed in the plates so that only the knuckle would project above the deck. Some of the doors in the protective deck should open upward so that the lower bunkers could be completely filled with coal. Those doors opening upward would close by their own weight, and might not need a locking device. An inverted ∩-bolt would be used for raising the doors, and this need not project above the deck, for a recess in the plate would permit the bolt to be dropped into place. Such an arrangement of doors would insure the rapid and close stowing of bunkers, and would also permit weights to be shifted rapidly from above. As the upper bunkers would be free of coaling trucks, there would be better opportunity to handle coal in the upper compartments.

EMERGENCY CHUTES SHOULD BE INSTALLED.

Several fixed chutes should lead from the fire rooms to that deck where reserve coal is carried. Then when a deck supply is carried this fuel could be supplied to the furnaces without passing through the bunkers. Where the fire rooms are narrow and contracted, these chutes might have to be constructed within the bunkers, but in the base of each there might be fitted an arrangement which would permit the coal from the deck to enter the fire rooms or bunkers independent of the other. With such *emergency* chutes it would be possible to use all deck loads without disturbing any of the bunkers, and in case of heavy weather suddenly coming on, the deck load of coal might be quickly stowed below in the unused fire rooms. There would be times also when these chutes might be used for ventilating purposes. It will be understood that these chutes should be absolutely independent of the main bunker openings, and would provide a means of supplying the fire rooms otherwise than through the bunker doors.

In times of emergency when sufficient coal could not be passed through the lower bunker doors, then that part of the ship's company not standing regular watch or detailed for special work

could pass the coal from the upper bunkers through the deck plates to the berth deck. This coal could then be carried to the emergency chutes and kept in readiness for being lowered below.

With the present narrow lower bunkers there can be no hurrying of the coal supply to the furnaces no matter how much assistance may be available from deck.

If there were a large number of openings to the upper bunker, then plenty of hustling could be done there, for every opening would mean that a separate gang of men could be utilized. It is very probable that where the lower bunkers are narrow more coal could be passed through these emergency chutes to the fire room than could be passed through the lower bunker doors. Another important advantage of the emergency chutes would be in case of any of the lower bunkers filling with water. Coal from the upper bunkers could then be supplied to the fire room nearest this impaired bunker through the fixed emergency chutes. There would be no battle plate fitted in this chute any more than there should be a plate fitted in the forced-draft air duct.

There might not be many occasions where these emergency chutes would be used, but when they were required their installation might be the means of saving the vessel or of determining the fate of a battle. Probably none but those who are responsible for the condition of affairs in the fire room realize how difficult at times it is to get a sufficient supply of fuel. If this weakness could be appreciated in its fullness by the commander-in-chief of our fleets, some war vessels would not be permitted to go to sea until the evil had been corrected.

GETTING COAL FROM BUNKERS.

One of the weaknesses of the modern battleship is the difficulty at times of securing a sufficient supply of fuel for the furnaces. In as late an issue as that of November 9, 1900, "Engineering" of London, in its leading editorial, "*The Naval Position*," makes the following declaration upon this subject:

"When one considers the complication of a modern war vessel, it is little less than a miracle how the engines are made to turn and the ships get out of harbor. If full speed is needed

fifty or sixty deck hands must be sent down to trim coal, which otherwise could not be got out of the bunkers quick enough for the stokers to keep the fires going. It is curious to think what would happen in real war if our ships were in chase of an enemy of about equal speed. The deck contingent would be needed at their guns and other positions to engage the enemy; but unless a good number of them were below in the bunkers, the enemy would escape, because there would be no coal for the stokers to put in the furnaces. Of course, there is the reverse case of the enemy being in greater strength and chasing ship. It would then be a nice problem for the captain to decide when he should give up steaming and call his men up to the guns."

If such things are true of some of the best war ships in the world, it may be pertinent to inquire what is the condition of affairs upon some of the battleships which we possess, and where the coal was put "in any space that happened to be left."

It must be remembered that by reason of the structural arrangement of the lower bunkers, they are really nothing but wing passages. There can be no hurrying of the coal supply in this direction, no matter how many men are ready or available for work.

Probably in not one of our large warships built within the past ten years could coal be supplied for a period of twelve hours in sufficient quantity to feed the furnaces when under heavy forced draft. Admiral Sampson has asserted this of the *San Francisco*, and that vessel is better than some other cruisers in this respect.

RAPIDITY OF COALING.

In regard to the rapidity of coaling, there are so many factors that enter into this question that nothing can be determined from records except to compare the performances of vessels of the same class. The following are some of the elements that will influence the speed of the work: the state of the weather; the number, character and size of the lighters; the condition and character of the coal; the number and location of the winches;

the number of men employed; the amount of deck surface available for receiving baskets or buckets, and the facilities for bunker stowing.

Several of the foreign battleships have put a thousand tons on board in about six hours, but one is not told of these performances whether or not it was necessary to do any trimming. On the lakes a thousand tons of ore have been placed in the hold of the vessel in a single hour, so that, compared with this performance, the evolution of the foreign battleship might not appear as particularly creditable. On the lake transport, however, there were series of large hatches extending nearly the full width of the vessel, and the ore simply ran down a row of inclined chutes.

Except when comparing vessels of the same tonnage and design, coaling records tell nothing. So well recognized is this fact in England that no attempt is made to induce one war vessel to adopt the method of another when coaling. Each ship has its favorite coaling arrangement, for which all latitude is allowed. The spirit of rivalry between squadrons and individual ships is very keen, and the resourceful and ingenious are induced to rig special arrangements for expediting work. Experience and thought naturally suggest the best means for rigging whips, installing Temperlies and running lines of baskets where it is possible to do so.

THE BEST MEANS OF COALING.

It is the question of coaling warships that this article treats of, and the views expressed have no application to the question of loading barges and colliers where trimming is not necessary. In my opinion the most rapid way of taking coal on board a warship *when her crew has to unload the lighter* is by means of baskets, the gross weight of which should not exceed seventy-five pounds. It might even be best to have baskets supplied which would not hold over fifty pounds, by reason of the fact that there are now so many apprentice boys comprising the crew of the seagoing ships. This method of coaling is carried on practically throughout Asia and in many ports of the Mediterranean as well as in the West Indies. Where the passageways are narrow, the

hatches small, and the bunker openings contracted, and where a large number of men are available, it is the best way of doing the work. Where bags are used time must necessarily be lost in filling and emptying them. Where the heavy bucket is employed trouble is constantly being had in their manipulation. And whenever a whip or chain is used, it will be found that much time is lost by some part of the gear occasionally giving away.

SHIPBUILDERS ARE INTERESTED IN THE COALING OF WARSHIPS.

In designing vessels for the merchant marine the shipbuilders, of necessity, are compelled to give special consideration to the manner of quickly and completely filling bunkers, as well as to the arrangement for securing a sufficient supply for the furnaces. Since the weakness of warships, at least so far as bunker arrangements are concerned, must be apparent to the shipbuilders during the course of building the vessels, the thought suggests itself, Should not these firms take official cognizance of the matter, and make special efforts in urging improvements? That warship which will be looked out for in this respect by the contractors will be a perpetual tribute to their ability to appreciate the importance of details. Any trouble or expense incurred by them in perfecting improvements will be returned many fold. It is extremely probable that all recommendations made by the shipbuilders for the improvement of the coaling arrangements would receive special consideration. If their protest against existing arrangements will receive consideration, then at least a moral responsibility rests upon them to effect improvements.

The builders of the *Oregon*, in their determination to consider the Nation's interests as well as their own, strove to even excel the specifications of the Department. It would be difficult to make any one now believe that it was not a paying investment for the Union Iron Works to do work in the manner that was done on that famous ship. Some other shipbuilding firms may find it equally profitable to initiate improvements in coaling arrangements, for should success attend their efforts, their good work would not go unrewarded. It would be but a short time before the service at large would know and appreciate the special

excellence of any vessel that had a marked superiority over her counterparts in coaling arrangements.

THE USE OF THE TEMPERLEY CONVEYOR.

For description see Vol. X, page 1154.

During the past five years much has been written about the *Temperley* conveyor solving the coaling question. Outside of the British service, however, there is only one nation which has purchased more than ten of these contrivances. There are conditions which make them exceedingly desirable, but these conditions are not likely to be found on board a warship. It must not be forgotten that the *Temperley* takes up considerable deck space for handling the coal, and so it is not possible to rig them very often on board a cruising ship. On several of the British battleships there has been a keen competition between the *Temperley* and a whip rigged by the ship's force—the *Temperley* has been beaten as often as it has won over the whip.

On the hulk or coal barge, or on the pier, they may be desirable, for there plenty of room to install them may be found. Where the conditions are such that the coal is simply lifted out of one hatch from one ship and transported to a hatch directly abeam on another ship, the *Temperley* would, of course, surpass some improvised arrangement, since the appliance has been practically designed for such conditions. Unfortunately these simple requirements do not exist in coaling warships.

For two days I had the opportunity of closely watching the performance of this appliance. Our ship was tied to an old British cruiser that had been converted into a coal hulk. The arrangement of hatches and the location of the *Temperleys* on board the hulk had been planned to the satisfaction of experts. The conditions could therefore be presumed to be exceptionally favorable to the working of the *Temperley*. Three transporters were placed at our disposal and experts from shore were detailed to work the winches. It was well understood that the system was under test, although nothing had been said upon the subject. Previous to the coaling the winches were examined and tested and run for short intervals to see that everything was all

right. The coal in the hulk was dry. The weather was comparatively pleasant. Despite all these conditions favorable to rapid coaling, there was hardly a time when one of the transporters did not cause some annoyance, and there never appeared a time when the coaling bags were under perfect control of the man running the winch. The average amount handled per hour by each transporter was less than twelve tons throughout. The character of our bunkers prevented more than three *Temperley* transporters from being worked at the same time, but during the greater period of coaling there was no interference with the continuous working of the arrangement.

From what I saw and learned during that coaling I am convinced that the *Temperley* transporter cannot be compared with American machines that have been designed to do the same work. The appliance is simply superior to the average whip in the fact that it has some patent couplings and devices which makes it advantageous for special work. Almost equally good fittings can probably be purchased from some of the large machinery supply houses. It costs something to rig a *Temperley* transporter, but I believe that there is enough mechanical talent on board every warship to rig an arrangement at the same expense which will better meet the special conditions existing. The special function of this appliance is to quickly remove coal from the hold of a vessel. Where the coal has to be transported to a deck which has been cut up by hatches, turrets and stacks, the advantages of the *Temperley* are seriously impaired.

RESERVE COAL SHOULD BE KEPT AFLOAT.

In time of war I am convinced that it is of primary importance that as much as possible of all reserve coal should be kept afloat. Barges, hulks and colliers should be used for this work. We cannot have too great a variety of such craft, but it is extremely necessary that special attention be given to their construction. For warship purposes these coaling vessels should be as long as possible, so as to permit at least two separate booms to be used for whipping the coal. Wide and numerous hatches

should be provided, and all should carry an ample supply of bags and baskets. Shovels by the gross should be supplied to these vessels.

Where the colliers are kept steadily employed, they should carry a contingent of stevedores who should handle at least all the coal on their own craft. Such help from the colliers would spur the sailors. The slight financial saving that is now effected by having the crew coal ship is more than counterbalanced by its harmful influence upon the discipline of the ship's company. With such a contingent on board the colliers, the fleet would not only have a reserve of coal afloat, but there would be a reserve of men to assist in the evolution of coaling ship.

There are many reasons why reserve coal should be kept afloat and not landed. The quantity of the coal would be preserved, due to the reduced number of handlings.

I have been reliably informed that experience has taught the dealers at Trinity Building, New York, that every time coal is handled there is a depreciation of 5 per cent. in value, due to the loss of weight, breaking up of the coal and the volatilization of the hydro-carbons. One need not go to sea many years to appreciate the fact that when coal is handled several times in close quarters, there is practically no lump in it. When in this state there is a wasteful expenditure in consuming it, because so much of the fine coal passes through the grate.

With coal afloat, time can be saved in getting it to the warship, for the barge or collier seldom draws as much water as the cruiser, and, therefore, it is easier for the coal to be taken to the war vessel than the war vessel to secure to the pier or wharf. With a vessel acting singly or even with a fleet cruising, it will nearly always be possible to telegraph ahead and have the collier or barge ready for unloading.

There need be no waiting for a tide to reach the coal pile when the coal is afloat. With the coal on shore there must be delay. That coaling station which is not beyond the enemy's shell is of doubtful value, and therefore the warship has invariably to wait for a tide both in going to and coming from a coal wharf. When alongside the wharf, it is practically impossible to prevent the

smuggling of liquor, and other elements destructive to discipline are introduced.

In the British service experience has taught them never to send a *battleship* alongside a wharf or coal pile, and if that Navy, with its long and wide experience, has taken such action, there must have been some good reason for impelling them to do this.

There are also strategic advantages in keeping the coal afloat. With coal stored in this manner it can be more quickly and satisfactorily distributed to the several war ships. There will be no necessity to reduce the fighting force by sending individual ships at intervals to distant places for filling bunkers. At a fraction of the coal consumption that will be required to move a warship, the barge or collier can be shifted.

Of course, it will entail a heavy expenditure to keep the reserve coal afloat, but it will probably cost as much to coal from the wharf. That method is the cheapest which will detain the fleet the shortest time, and thus permit it to more quickly seek or avoid the enemy.

In naval warfare, time and speed are almost convertible terms, and if one has an intrinsic value then the other is of equal financial worth. On certain ships a bonus of $50,000 has been paid for each quarter of a knot secured above a contract speed. We have cheerfully paid for this increase, while at the same time we have exacted a penalty for any failure to obtain the contract performance. And it will be found equally advantageous to pay for time gained in any other way.

The loss of time due to coaling was brought forcibly to mind off Santiago, and yet as one writer declares:

"We put up with coaling methods and arrangements which consume so much valuable time in an emergency that if a half knot represents $100,000, the coal taken in may often represent its own weight in gold."

ONLY SUPERIOR COAL SHOULD BE USED ON WARSHIPS.

It is poor economy to purchase any but the best of coal for warships, since the first cost is seldom an index of the value of coal when it reaches the furnace. Coal deteriorates with each

handling. From the time it leaves the mine until it reaches the fire rooms of a warship it is shifted much oftener than one would believe possible until he gave special consideration to the matter.

In the upper bunkers of one vessel to which I was attached there were vertical bulkheads for supporting the turrets, and some of the coal had to be handled three times to stow it there, and three times again to shift it to the lower bunkers. Most of the coal which ever reached the furnaces from these bunkers was little better than coal dust when it was thrown into the fire.

It is a fact that the best coal does not disintegrate and powder so quickly as the poorer quality, for the hydro-carbons make it less friable.

On distant stations, coal which may be bought at Hampton Roads for $4.00 probably represents a value of at least $10.00. An increase, therefore, of even fifty per cent. in the first cost would not add very much to the net value when delivered to the warship.

The very best coal is required, since it costs just as much to handle and transport a poor quality as a good one. The depreciation in quality is greatest in the poorer grade. There are losses, also, in the fire room, which are the greatest when a poor quality of fuel is used.

It might be advisable, therefore, to prescribe that for distant stations at least only screened coal should be taken into the holds of colliers.

COALING STATIONS.

Of late years, both in diplomatic and military circles, there has been a progressive interest taken in the subject of establishing coaling stations; but there will be and always has been considerable divergence of opinion as to the degree of their usefulness, because those directing naval policies have quite different views as to the scope and extent of such a plant. If by a naval base is meant where target practice can be carried on, where supplies and stores as well as fresh water can be secured, where repairs can be made to the hull and machinery, and where ships can be docked, then coaling stations are of incalculable benefit

to every nation that aspires to military power. If the term, however, refers to the building of sheds and the installation of excellent machinery for storing and handling only cargoes of coal, then the plant may be of doubtful value.

The coal pile in itself may be an incumbrance to the power possessing it, particularly if there are no land defenses for its protection, and if its location is distant from the lanes of commerce. Any powerful opponent might destroy the place if unfortified, and any long journey for coal upon the part of the warship would leave very little fuel available for blockading or fleet purposes.

The establishment of a coaling plant in any port which commerce has avoided can contribute but little to the strategic value of a nation's line of defense, for any harbor that is unused by the mercantile marine undoubtedly possesses some inherent disadvantages.

Coal is not only perishable, but it is getting too valuable and scarce to be bottled up. Probably no article in common use that is of a bulky nature has so short a reserve supply in stock. This is because no reserve is kept on hand, either at the mouth of the mine or at the shipping point, since every storage means at least two handlings. Each handling means depreciation in the value of the commodity and loss of time in shipment.

The recent coal strike in the anthracite region showed how small a reserve it was possible to accumulate, even after the dealers had a month's time in which to fill their bins. In less than three weeks from the time the strike was on the coal carrying and mining companies had to yield to demands that seemed exorbitant when first made.

Any place will not, therefore, do for the storage of coal. The selection of a coaling station is a question that is worthy the consideration of the ablest boards of officers. The storage of coal for naval purposes must mean the purchase of land, the building of sea walls, the construction of sheds, the installation of expensive handling machinery, and eventually the erection of fortifications. A mistake in the selection of a coaling station may bottle up coal that is a necessity to a fleet, and the time may

come when a nation may be fortunate indeed if the only result of the mistake is to make the value of the fuel received from such source partake more of the nature of a precious ore than a combustible.

Too much conservatism can not be practiced in establishing coaling stations, for, independent of their inherent weakness and disadvantages, it is not unreasonable to presume that in attempting to acquire territory for such establishments nations may find it an indirect means of provoking war. The establishment of permanent coaling stations must be done with great deliberation and conservatism, for since war brings on great surprises, new coaling bases will have to be secured with new conditions.

COALING STATIONS WILL BE ESTABLISHED IN TIME OF WAR NEAR FIELD OF OPERATIONS.

If our war with Spain showed that importance should be attached to any particular military principle, then the securing of a naval base as near as possible to the field of operations has probably risen to one of supreme value. Such bases not only permit coaling, but also repairing, and no matter how desirable it may be to coal on the high sea, the blockading fleet will always receive the bulk of its supply at some base. Particularly will this be the case when our administrators come to the conclusion that when engaged in this service both ships and crews require an occasional rest. With such a base for the ships to occasionally visit, it ought to be possible for stevedores to do the coaling and the mechanics from the repair ships to do the overhauling.

At such bases in time of war, and in sheltered anchorages in time of peace, we should make use of barges fitted with conveying machinery. And in seeking such appliances we should not expect private parties to undergo all the financial outlay demanded in the development of the invention. We pay royalty for improved armor, have given a bonus for increased speed, subsidized the merchant marine and offered bounty for the production of certain articles; then why should not the Government assist, either directly or indirectly, in perfecting arrangements for increasing the coaling of ships?

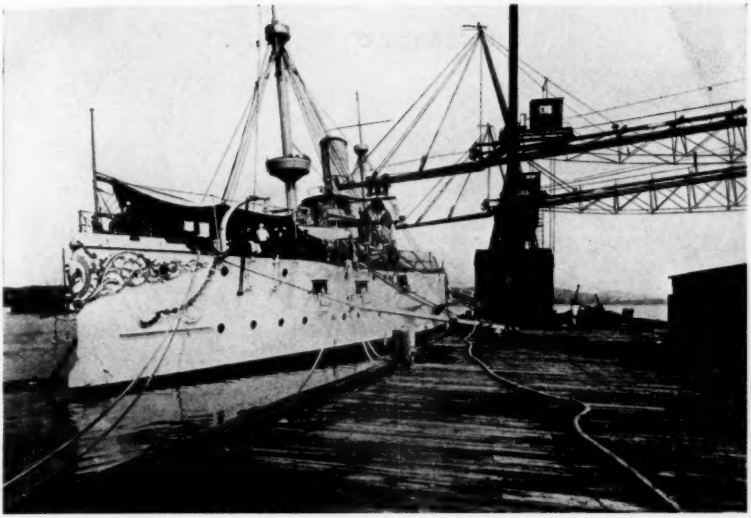
COAL-HANDLING APPLIANCES AT OUR NAVAL STATIONS.

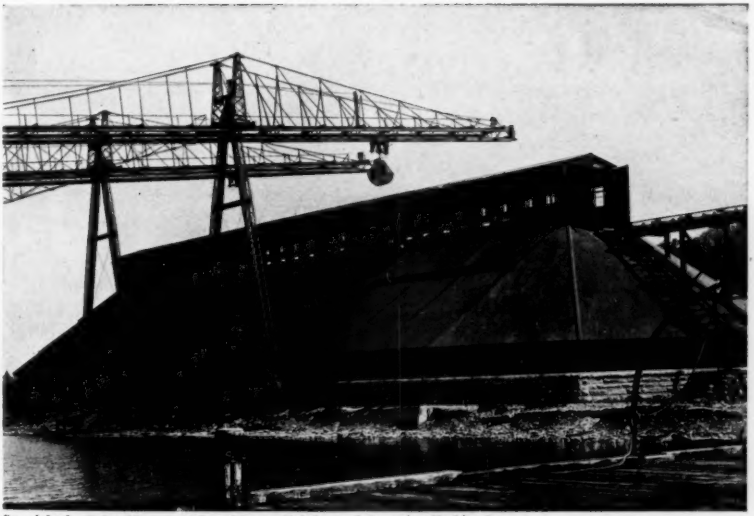
Whatever differences of opinion may exist as to the location of some of our coaling stations, there can be only commendation for the character of the coal-handling appliances that have been installed. The illustration showing the U. S. battleship *Texas* taking coal from the stock house at New London, Conn., will give an excellent idea of the bridge-tramway coaling plant that has been erected there. This plant was constructed by the *Brown Hoisting and Conveying Machine Company, of Cleveland, Ohio*, and is typical of the plant installed at nearly all our naval stations. It will be observed that there are two bridge-tramways for handling coal. Each tramway is absolutely independent of the other, and consists of two piers with a connecting bridge, on which runs the trolley. If it is desired to extend the capacity of the plant, then additional bridge tramways are installed.

The front pier of each tramway contains the engine, boiler and machinery, and travels up and down the dock under steam on a double railroad track. The back, or single-leg pier, is moved by hand power, and has an independent railroad track. Provision has been made whereby it is not essential that the two piers shall be moved at the same time, and therefore but little delay need result from shifting piers.

The stock house can be built at a considerable distance from the wharf, since each tramway has a span of 192 feet, with a cantilever extension of 102 feet over the storage building. There is also a 30-foot hinged apron connected to the front of the span, and this apron contains the unloading and rehandling machinery. Each machine has a pair of standard scales on the bridge tramway track, so that every load can be weighed. A single-rope grab bucket is used for transferring the coal. An equipment of skips is also provided for handling the coal in bags, this being a Navy Department requirement.

The storage building is entirely of steel, with galvanized corrugated iron covering. It has granite retaining walls, and a concrete floor. There are 38 hatches in the roof, each 15 feet square, through which the coal is put into and taken out of the





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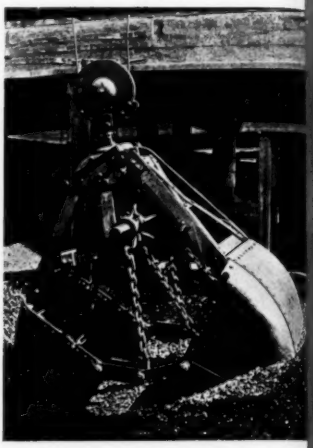
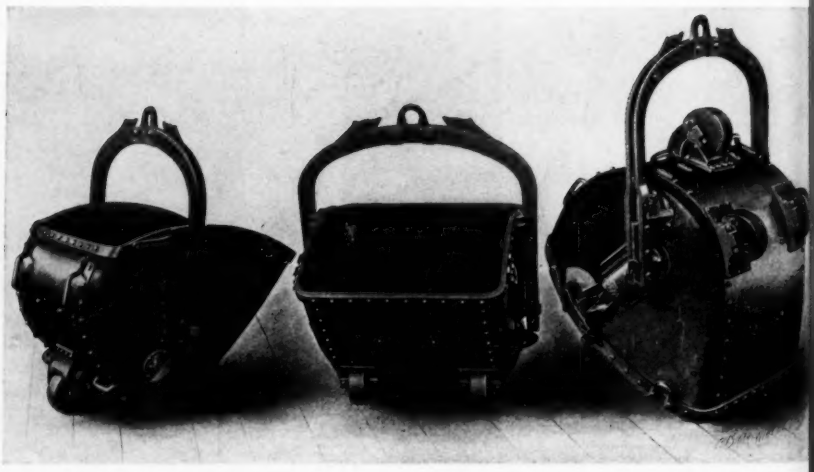
THE COALING OF WARSHIPS.

U. S BATTLESHIP "TEXAS" COALING FROM STOCK HOUSE AT NAVAL STATION, NEW LONDON, CONN.





AUTOMATIC GRAB BUCKETS AND TUBS USED BY THE BROWN HOISTING AND CONVEYING CO.

building. These hatches are counterweighted, and are operated by hand power from the inside. The coal storage capacity is 10,000 tons, but the design and character of the building will permit an extension to be quickly made. There is a railroad track which extends into the building so that the stock house can be filled from cars in case of necessity.

It will be noticed that all the machinery for handling the coal is outside the building, in the open, where it can be well taken care of and properly attended to.

The guarantee on each of the bridges was forty-five trips per hour, and practically a ton of coal can be carried on each trip. Bridges of exactly similar dimensions are transporting fifty-five tons of coal per hour, but these tramways are in constant use, and thus the personnel detailed for handling them become expert in their manipulation.

COALING AT SEA.

In the discussion that followed the reading of a paper before a British society, entitled "*Coaling ships in squadron on the open sea*," Admiral Colomb said:

"I am sure the English navy will always go where the enemy is, and will hold on to the enemy until it has finished with it. I know we cannot do that in cases where the enemy is in his port unless we have coal at our disposal there while at sea, or unless we have very large relays so as to enable us to keep a sufficient force watching the enemy while the rest of them are away coaling."

This is practically saying that the first line of defense of a nation must be the enemy's coast, and that such work must devolve upon a navy operating from a distant base. It is because the Anglo-Saxon has fought on this line that he is so powerful to-day.

Any nation that is unable to conduct war near the enemy's coast is subject to attack upon his own. Serious as the undertaking may be of building a navy capable of carrying on such work, yet it must be pursued, if for no other purpose than the maintenance of peace.

It is safe to say that in carrying war along such aggressive

lines as Admiral Colomb suggests, the question of providing a supply of coal will only be second to that of securing an adequate fleet for the operations projected.

It is because coal supply will govern the movement of the superior fleet that everything pertaining to coaling warships at sea should receive the careful consideration of the naval student and tactician, for that nation which will make a distinct advance in coaling warships will make a distinct advance in naval strength.

There is no nation that surpasses our own in its ability to get coal afloat into colliers and barges. If there is one particular advantage that we do possess over our commercial rivals, it is in the economy and rapidity with which we are able to handle material. In cranes and conveyors we are in the front rank. In methods of transportation such strides have been made that we have changed the conditions affecting the ore and coal-carrying trade, and as a result there have been made possible by our superiority in handling material the lowest freight rates in the world. With our unlimited and superior coal resources, and with our excellent industrial railways and coal handling machinery, the question of getting the coal afloat into the collier or barge, in the highest possible effective manner, has practically been solved.

This is but solving, however, the first part of the greater problem of coaling the war vessel at sea. The present difficulty is in getting the coal from the collier or barge to the deck of the warship. Able men within and without the Navy are giving careful consideration to this matter, so that we can look for a progressive, if not for a rapid, increase in the hourly amount that can be transferred when coaling from ship to ship is possible.

As the Navy must be the great beneficiary in any arrangement that will permit more rapid coaling of war vessels at sea, it would seem advisable that the Department should have a large fund at its disposal to help develop every arrangement that gives promise of improving matters.

SUPERIORITY OF AMERICAN COALING APPLIANCES AFLOAT.

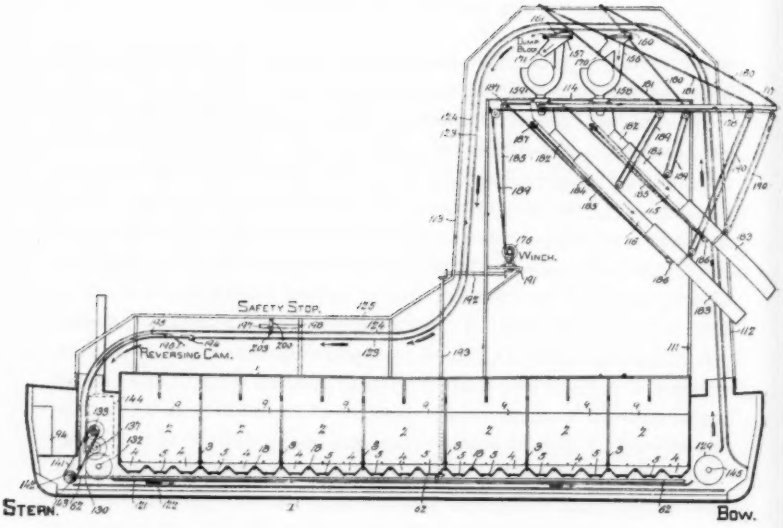
Our maritime and transportation necessities have compelled us to give special consideration to the question of handling freight

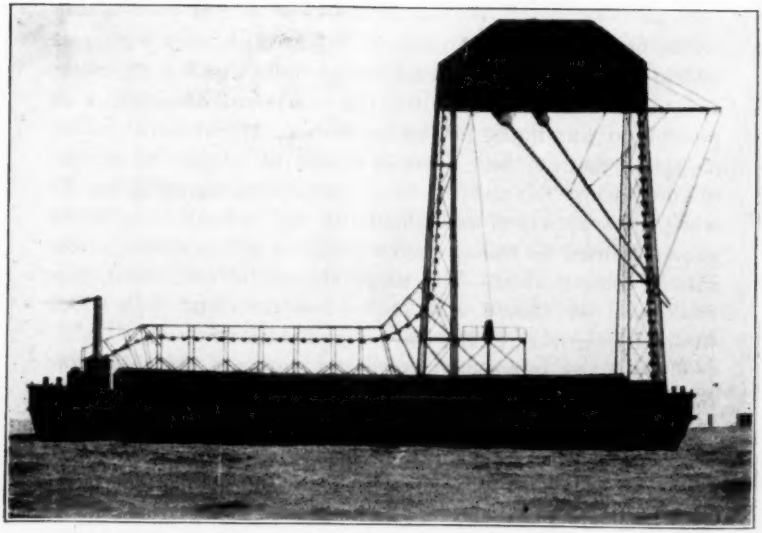
of every description both ashore and afloat. It is particularly because our necessities have compelled us to do so, that we have surpassed our commercial rivals in the construction and building of conveying and handling machinery. This superiority extends to handling freight afloat, and in several directions we have made distinct advances in appliances for the coaling of vessels. The first and probably the most important advance has been in adapting the elevator system to the coaling barge. We are certainly also in advance in constructing a marine cableway for coaling from a vessel in tow. In perfecting a freight-delivery vessel which can be safely anchored alongside another vessel even in a moderate seaway we have also forged ahead. In these three appliances we have therefore shown our superiority of any other inventions of like character that have preceded them. A brief description of each of these inventions is not only pertinent to this subject, but will be of interest to all those who have an interest in coaling war and merchant ships.

THE CLARKE AUTOMATIC COALING AND WEIGHING BARGE.

The first appliance referred to is practically a seagoing barge which ought to be particularly adapted for the Navy's needs. It is because I believe in putting the reserve coal afloat wherever possible in war times, as well as because I believe in coaling alongside, that our best energies should be devoted to making the ordinary collier and the large barge more adaptable for the work. The sphere of each should be well defined. The collier should be used for transportation purposes and for coaling under special contingencies. The barge should be used for harbor work, and we should now look for a particular type which would answer most of the Navy's requirements.

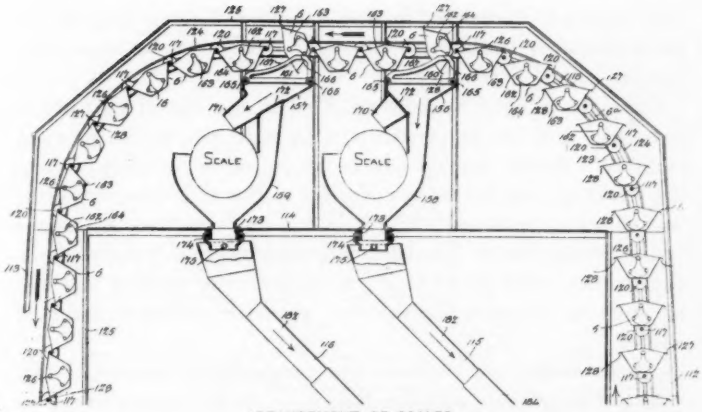
There is now in constant use in the harbor of New York the *Clarke Automatic Coaling and Weighing Barge.* In answering the requirements of the ocean greyhounds concerning cleanliness, despatch and reliability in coaling, the principal needs of the Navy have been met. The barge, by this appliance, is practically a floating coal elevator, and is loaded in the same manner as the ordinary canal boat. Its special merit is based upon the



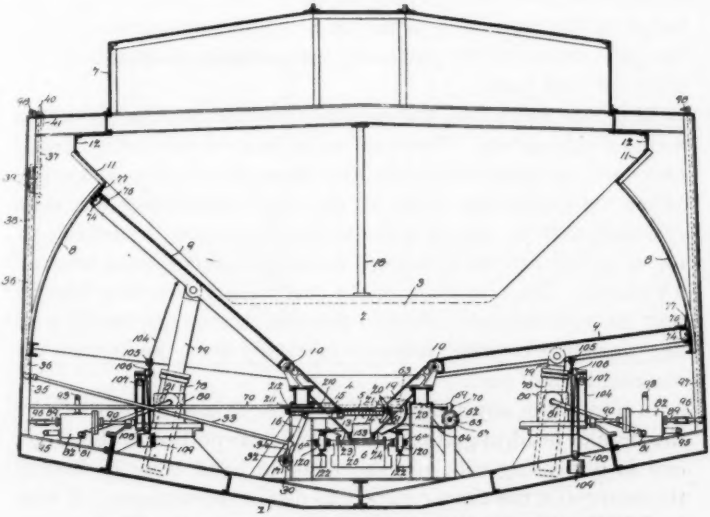


THE COALING OF WARSHIPS.

THE CLARKE AUTOMATIC COALING AND WEIGHING BARGE.



ARRANGEMENT OF SCALES.



ARRANGEMENT OF HINGED BOTTOM AND GRAVITY BUCKET CONVEYORS.

THE CLARKE AUTOMATIC COALING AND WEIGHING BARGE.

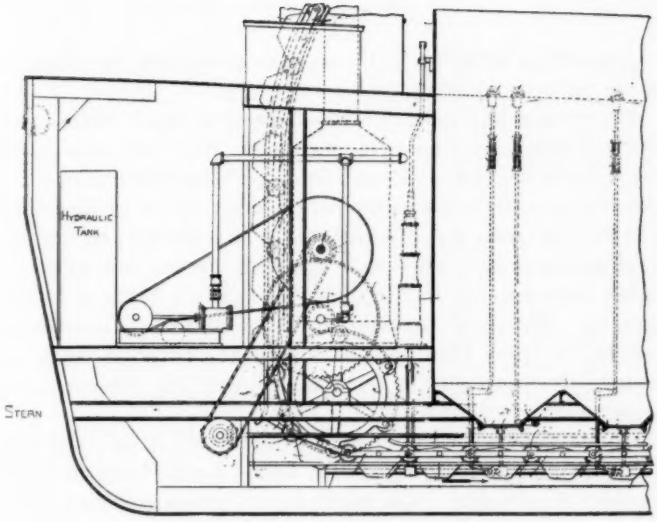
well sustained claim that for the handling of lump material for short distances, the endless conveyor has shown its superiority over all other contrivances.

Since the gravity buckets are filled in the lowest part of the vessel the hull can be constructed so as to give the barge great stability. As the hatches can be closed during coaling, and as the telescopic chutes deliver directly to the ship's openings, the war ship can be coaled while it is raining, a military advantage of inestimable value. In latitudes where there is a rainy season the coaling could go on at any time instead of waiting for days, as must be occasionally the case with the ordinary barge or collier.

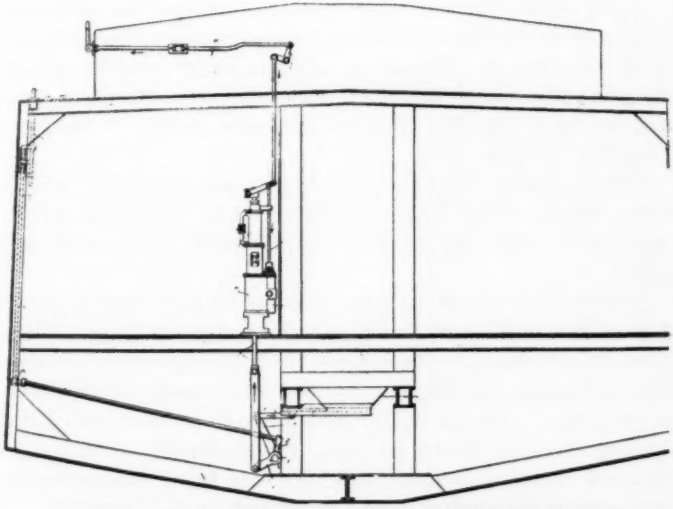
These barges are built on the compartment system, so that coal can be taken at any one time from all the compartments or from any end. An even trim of the barge can always be maintained, since the conveyor tunnel runs longitudinally in the center of the boat, and therefore whatever coal is taken out runs down equally from both sides to the gravity buckets. Any lifting of the barge by the head or stern can be prevented by simply opening the gate valves to the particular compartment from which it is desired to use coal.

The coal flows into the gravity-conveyor buckets through a series of gate valves. These valves are in close proximity to each other and are operated by one man through an hydraulic system. When the coal in the center of any one compartment has been removed, then by means of the hydraulic system, the iron flooring is canted and the bottom of the coal-carrying space assumes a V-shape. The remainder of the coal on each side then finds its way through the gate valves to the tunnel, thus dispensing with any shoveling or hand labor in removing even the last few remaining tons of coal.

In preventing any sudden listing of the ship or any settling by the stern or head, in getting at any particular portion of the cargo, and in dispensing with any shoveling or hand labor in feeding the conveyors, the *Clarke Barge* has distinct advantages. It may be incidentally mentioned that by hydraulic means there are



ARRANGEMENT OF CONVEYOR GEARING.



ARRANGEMENT OF HYDRAULIC SYSTEM FOR OPENING GATE VALVES.

THE CLARKE AUTOMATIC COALING AND WEIGHING BARGE.

"agitators" for breaking up the lump or preventing the clogging of the conveyor system.

The system has some special advantages which should particularly commend it for naval purposes. As it not only weighs but *registers* the coal delivered, there can be no dispute as to the amount actually received on deck. After the coal has fallen into the bin under the automatic scale, it is discharged through a cylindrical chute. This chute can either be led directly to the saddle-back opening in the ship's side, or to a hatch or bunker opening. With coal conveyed in this way there is a minimum amount of dust. One has only to see the barge in operation to note its superiority in this respect over any other existing arrangement.

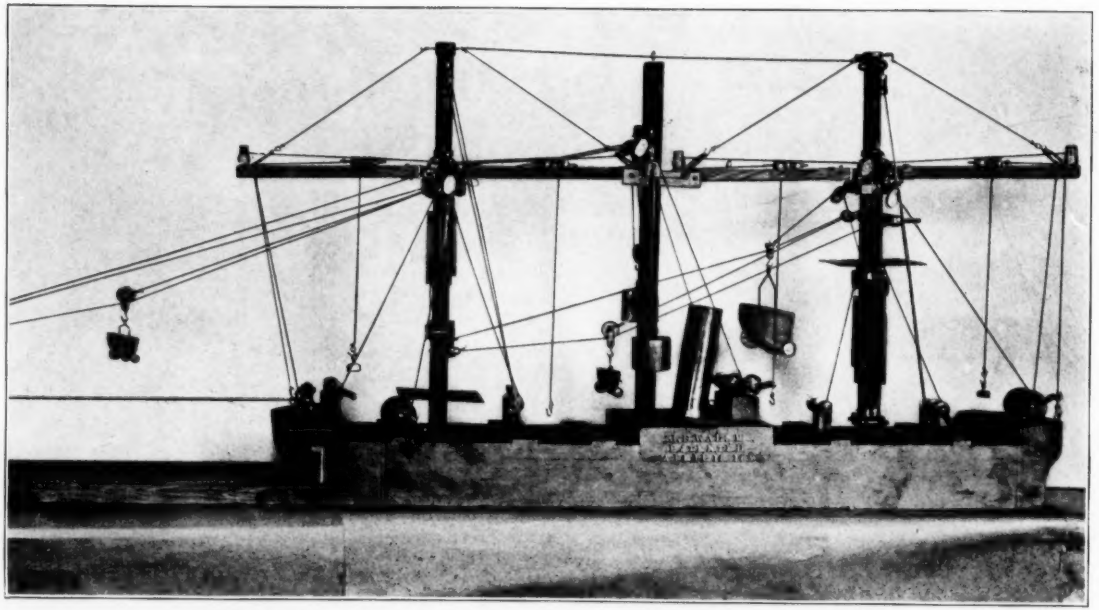
All the conveying and operating machinery is on the barge, even the coal discharging chutes being manipulated from the tower of the elevator. The barge has its own engine and boiler, and can deliver coal to the hatches or to the saddle-backs absolutely independent of the warship.

There is but little coal moving at any one time, the speed and regularity of the flow also being controlled from the tower by mechanical means. The gravity buckets and the trolley gear for elevating the coal to the tower are of approved standard type, and are so strong that they are not only capable of handling coal but even iron ore.

The appliance is capable of easily delivering over 100 tons an hour. With a single barge on each side of the warship, it will be possible to eclipse the record of coaling made in any naval service.

No men from the warship are required on the barge, nor need any of the ship's crew look out for whips or guys. Since there is a mechanical arrangement for breaking coal of extreme size, the bunker openings are not liable to become choked from large lumps. Since it is also possible to fit several coal chutes leading from the tower, the barge can go between two vessels and coal them, the amount each receiving being independently and automatically weighed and registered.

It would seem as if it was possible to apply this invention to



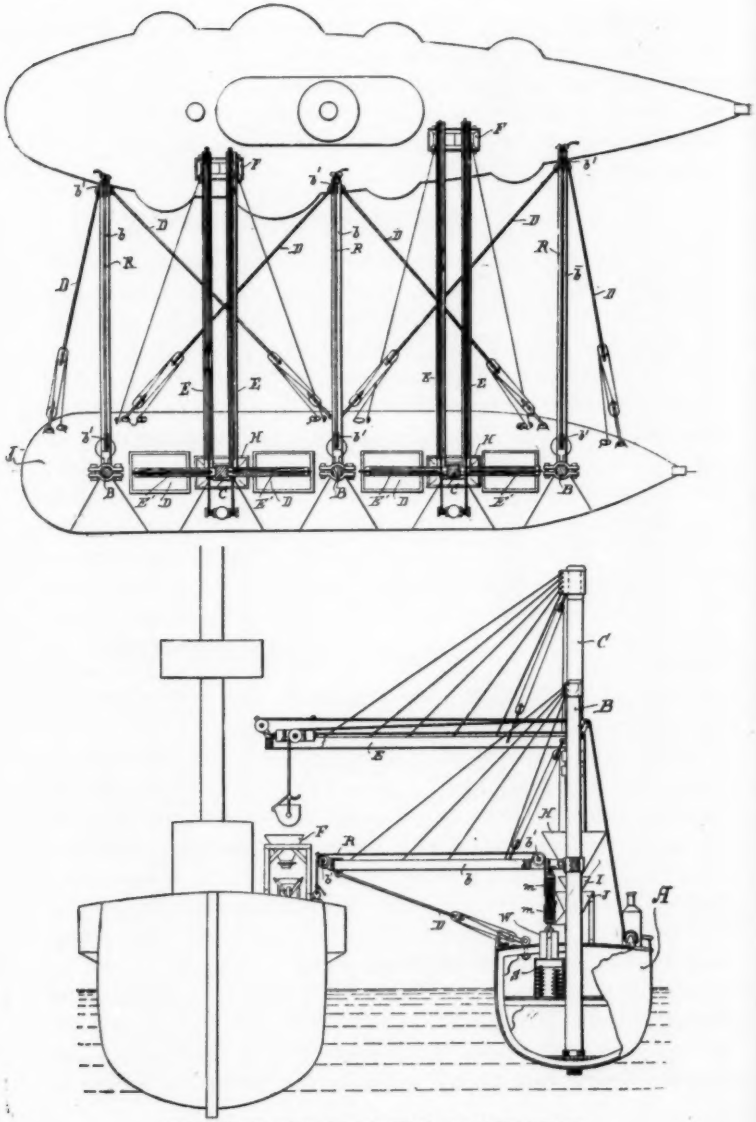
MODEL OF THE WALSH COAL AND FREIGHT DELIVERY VESSEL.

a collier of large size. The structural tower might be so designed as to permit the tower to be taken apart when the ship made long passages. Since it is presumed that the future collier will carry a large contingent of stevedores, it should not be a difficult matter to build up and take down the structure in a comparatively short time.

THE WALSH COAL AND FREIGHT-DELIVERY VESSELS

The next types of coaling vessels that are distinctly in advance of foreign ships are the inventions of a naval contractor in New York City, who for over forty years has loaded and discharged ships' cargoes. There is probably no general stevedore in this country whose experience has been so extended, and who has loaded and discharged vessels under more various conditions than this man, and therefore he ought to know something of such matters. One of his freight-delivery vessels is for delivering freight or coal when the vessel is in tow. The second of his inventions provides for coaling from a collier alongside the warship. In both the *Walsh* devices all the operating and compensating gears for the several conveying lines are contained on board the collier. As in the case of the *Clarke Elevator Barge*, previously referred to, the fact is recognized that the warship is already crowded with too many auxiliaries, and therefore the modern collier should be able to land the coal independent of any assistance from the warship.

In the *Walsh* contrivance for coaling from a vessel in tow, the breaking of the transmitting cable, due to the relative movements of the vessel from wave action, is prevented by a suitable compensating device. This device is a weight, preferably, connected to a loop formed by a portion of the cable. The weight is attached to a guide secured to the side of the mast. The weight is of sufficient mass to keep a normal tension on the transmitting cable. Any movement of either vessel which would tend to slacken or put strain on the cable will simply raise or lower the weight. To provide against the weight being lowered to the deck, a "take-up" for the cable is provided. Should the hawser break and the vessels tend to drift apart, thereby raising the weight to



THE WALSH COAL AND FREIGHT DELIVERY VESSEL.

the full limit, the "take-up" may be reversed and more cable paid out. It is intended that this "take-up" shall regulate the length of the cable and always maintain the compensating gear in operable condition. This is the essential feature of his device, and, if successful, must be one of great importance when coaling from a vessel in tow.

In the *Walsh* device for discharging from a collier alongside the warship, the principal feature is the method of anchoring the two vessels firmly together. There are three short masts fitted with long booms or outriggers. These booms are rigged at a short distance above the deck of the collier, and extend in an horizontal position at right angles to its longitudinal axis. They are stayed by suitable vangs and guys. Upon the end of each boom and near its foot block are mounted sheaves for guiding an anchor rope. This anchor rope passes through two pulley blocks, and from one of the pulley blocks a heavy weight is secured which rests upon a spring cushion. Since one end of the anchor rope also passes through sheaves on the boom, and is secured to a cleat on the warship, any rolling of either vessel changes the tension of the rope. With the proper selection of weights, the anchor ropes thus secure both vessels together at a desirable distance from each other. The weights allow an independent movement of each vessel as might be due to a moderate sea-way. By means of a winch the anchor rope can be either slackened or tightened. There is a winch for each of the three anchor ropes, and these winches are placed on the collier where they will not interfere with coaling. The device may really be described as three boom fenders, with the additional provision that automatic arrangements are made for breasting off the collier when there is a heavy wave motion. The invention is one that is at least worthy of trial by the Government.

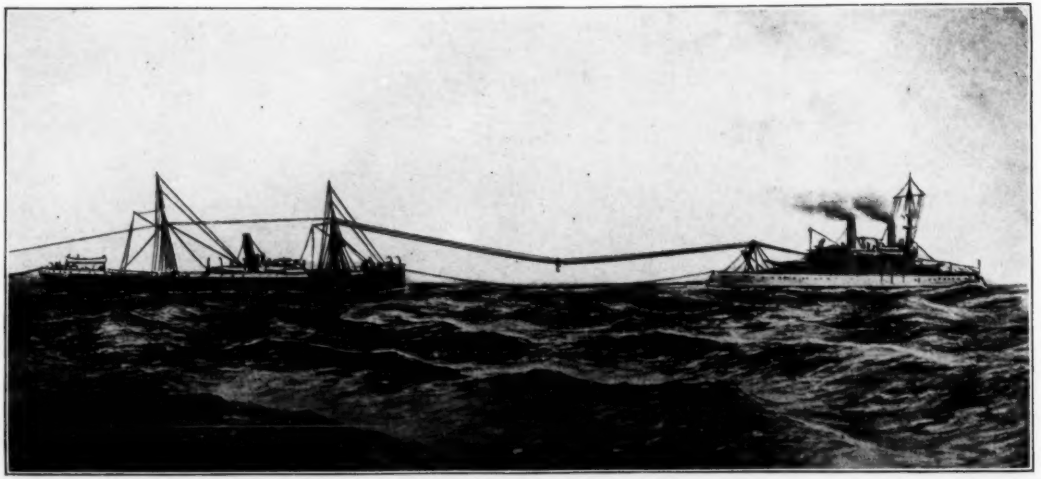
MILLER MARINE CABLEWAY.—COALING FROM SHIPS IN TOW.

In coaling from a vessel in tow we have undoubtedly had more success than has ever been heretofore secured. The experiment of coaling from the U. S. collier *Marcellus* when in tow of the U. S. battleship *Massachusetts* has attracted much attention, both at home and abroad. The *Marcellus* was fitted with

the *Miller Marine Cableway*, an appliance that can be regarded as a development, for much time and thought and considerable money has been expended in perfecting its details. A practical test of the apparatus was made at sea under the direction of a board of naval officers. The apparatus for three successive days had a series of trials, and during that period the ships steered in various directions—head on, quartering, and in the trough of the sea. The speed maintained was from five to six knots. The distance between the ships was from three hundred to four hundred feet. The sea was smooth on the first day, moderate on the second and a little rough on the third. Twenty to twenty-four tons per hour were transferred during the period of the test.

The invention is quite simple in principle, but quite a number of the details for manipulating the carriage are covered by invention. There is an elevated cable leading from the mast-head of the collier to sheer poles on the warship and back again. The engine for working this cable moved in the same direction all the time, and was located just abaft the foremast of the collier. The cable was led over a pulley at the masthead and thence to a pulley at the head of the sheer poles. The load carriage was supported by this cable. It was supported with a slipping grip on the upper part, with wheels to run on the lower part. An auxiliary rope, known as the "sea-anchor line," was stretched above the two parts of the cable line. This rope was attached to a special appliance on the superstructure of the war-ship, and rested in a saddle on the sheer poles; thence it led over pulleys at the head of the foremast and mainmast of the collier and on astern several hundred feet to the sea. On the end of this rope a drag, or sea anchor, was attached, made of canvas in the form of a cone. The dimensions of this sea anchor were dependent upon the speed at which the coaling vessel was moved.

The commanding officer of the U. S. S. *Massachusetts* declares that the sea anchor was the key to the whole question, for without the sea anchor the trolley could not be manipulated. By reason of the pitching of the vessel it was not possible for the sea anchor to be a perfect compensator, and therefore some other device must be substituted for controlling this tension. The



THE COALING OF WARSHIPS.

THE MILLER MARINE CABLEWAY.

THE COALING OF WARSHIPS.

TAKING COAL ON BOARD THE BATTLESHIP "MASSACHUSETTS" AT SEA, WITH COLLIER IN TOW, BY MEANS OF MILLER MARINE CABLEWAY.

inventor proposes to so improve the sea anchor as to overcome the difficulty. This disadvantage, however, might be overcome by the use of a tension engine in lieu of the sea anchor. The pertinent question then suggests itself, Where can room be found for such a machine in case it is to be a special auxiliary? From a naval standpoint it would seem advisable to try and give up all hope of installing any special coaling appliance on the warship. It is the opinion of the inventor that he can devise some way of operating the marine cableway from the warship without adding to the complexity that now exists. He has even stated, "that if he is unable to do this he would acknowledge that he was beaten." It is to be presumed that his plan modifies the deck winches found on board a warship so that they may operate the marine cableway at sea. Without, therefore, taking up any additional deck space, and without adding to the weight carried, a warship equipped with this special winch could take coal, provisions, supplies or ammunition from a collier or from a captured ship when in tow.

The winches now in use on board the warship are compact machines, and it may be somewhat difficult to extend their sphere without making them take up more deck space or increasing their weight. It is to be hoped, however, that the inventor of the marine cableway may be successful in his effort to construct a winch that will accomplish the purpose intended.

There will be occasions when the attempt will have to be made to coal on the high seas even in rough weather. In such emergencies the necessity for coal on the battleship will justify any expenditure previously incurred in making preparations for such exigencies. For this reason every possible collier should be equipped with some appliance like the Miller invention.

The occasions, however, will be very few when such extreme measures will have to be resorted to, and this is why we should make preparation for receiving practically all our coal from a vessel that is alongside the warship. We can also count upon it as a certainty that practically all the coaling will be done in harbor or where there is an anchorage and shelter from the prevailing wind and sea.

With large colliers this appliance ought to work best, for the

larger the vessel the more room for special appliances. It is possible that in large colliers the strain on the towline might be sufficient to maintain a tension in the main cable of the Miller conveyor, and thereby employ a tension engine in lieu of the sea anchor.

A MORE EFFICIENT COLLIER SHOULD BE DESIGNED.

This coaling question is important enough to receive the consideration of experts within and without the service. Primarily, however, it should be the policy of the Navy to try and effect improvements which will make it possible to do better work with vessels lying alongside one another. The following are a few pertinent thoughts which suggest themselves in regard to this subject:

Should the colliers be larger? Should not colliers carry a goodly number of fenders of various forms and sizes which might help matters somewhat? Is it not possible that heretofore the colliers have carried too few trained men to unload them efficiently? Does any nation possess a collier whose hatches and decks, as well as coal handling arrangements, were particularly designed for naval purposes? Has oil been used under various conditions while coaling at sea, for the purpose of making the ships ride easier? Has any warship been seriously injured in efficiency when coaling at sea? With the great advances that have been made in the malleability of structural material would it impair the collier to get some heavy dents? The question of bagging the coal on the collier is one that should be investigated, for it is surprising how rapidly and expeditiously bags can be handled.

It will not do to simply land loose coal on the warship's deck. With the war vessel either rolling and pitching, even moderately, it is not an easy matter to transport coal along or across the deck. It has been asserted by a man who has had extended experience in supervising the loading and discharging of cargoes, that when a ship was listed only ten degrees, it was impossible for an efficient stevedore to move coal along the deck, either with a truck or wheelbarrow. Even when a second man pulled the barrow or truck, there was difficulty and danger in the undertaking, since the truck was liable to roll back or capsize the

THE COALING OF WARSHIPS.

CARRIAGE WITH LOAD ATTACHED—MILLER MARINE CABLEWAY.

NOTE.—THE UPPER ROPE IS THE SEA ANCHOR LINE: THE TWO LOWER ROPES ARE THE CONVEYOR LINE.

moment the stevedores stopped pushing or pulling. Upon such occasions the value of small bags would be very apparent.

Those who go to sea are therefore almost a unit in believing that the key to the coaling question must be fitted on the collier and the barge and not on the warship. It is, therefore, regrettable that inventors seem so closely wedded to the desire to install so much special machinery on the warship, for marine engineers, naval constructors and commanding officers from experience realize that too many auxiliaries are there already. With such opposition it seems hardly possible that inventors will be permitted to install anything that is going to take up additional room on the warship even for such a desirable purpose as coaling ship.

It is to be presumed that those who design and navigate vessels, as well as those who are responsible for the efficiency of the numerous auxiliaries, have a pretty clear conception of the difficulty and disadvantage of finding space for any additional appliance on the warship. Unless one has served in the Navy, he can hardly realize the value and importance of clear deck space, for the installation of an additional auxiliary may not only interfere with drills, but seriously impede the working of the guns, the hoisting of boats, or the handling of supplies.

LARGE COLLIERS NECESSARY FOR NAVAL PURPOSES.

The development of the Atlantic liner as well as the warship is along the lines of both size and speed, and the same can be said of the collier. With a large collier will come large hatches, and with increased deck space will come increased facilities for rigging Temperleys and special winches. It can, therefore, be expected that with these increased advantages the question of coaling, both from alongside and when in tow, may be greatly simplified.

The collier is comparatively economical in its cost for running and maintenance. Since it has few auxiliaries and there is plenty of room for the installation of the various machines, the cost of repairs is reduced to a minimum.

In past years the strongest objections that were made to the building of vessels of large size were based upon the fact that

there were few docks where such vessels could be repaired, there were few harbors which they could safely enter, and that there were no facilities for loading and discharging large cargoes quickly. It has been asserted that the *Great Eastern* failed to be a paying investment because it took too long a time to load and discharge her cargo. With the improved facilities for handling cargoes that now exist, and with dredged harbors and large docks, the objections of the past have been overcome. The fact also that the displacement of the coaling schooners has been enlarged several times, shows that the tendency is in the direction of large freighters for the merchant marine, and surely we can make no mistake if we increase the size of the colliers also.

If a large collier will help to solve the coaling question, it will also help to solve the transportation question for the Army. In Europe there is now a tendency to use very large colliers, and to design such ships so that they could be used at comparatively short notice and expense for the transportation of military supplies, if not for troops.

In the movement of British troops and supplies to South Africa, as well as in the case of the United States sending stores and men to the Philippines, it was found that the larger the ship the better the service; and therefore we should see that it is possible to secure a collier transport of large size that would be convertible at slight expense and in a short time for the use of either Army or Navy.

DUTY OF THE NAVY TO INVENTORS WHO HAVE IMPROVED FACILITIES FOR COALING WARSHIPS AT SEA.

During the past year the Board of Construction, in a report to the Secretary of the Navy, practically declared that it was their opinion that the Holland Submarine Boat Company should be allowed even more than a reasonable price for the construction of their boats. This action was taken in view of the fact that the Holland Company have gone to great expense in developing the boat to its present condition. There are any number of precedents to show that the Government recognizes the claims of individuals to financial assistance in developing appliances that are useful for military and naval purposes.

The Navy Department should be allowed a contingent sum large enough to experiment with every appliance for coaling ships at sea that gives promise of future usefulness. Where inventors have gone to great personal expense, but have made progressive improvements, there should be some method by which they could be reimbursed for every outlay incurred. This should be done for two reasons: First, because the Navy has been the recipient of valuable information which may be put to use in the future, and it seems but right that even the Government should pay for what it has received. Second, because it will encourage other men to give consideration to the subject. With many minds at work improving matters, it is reasonable to expect that the problem will be more quickly and satisfactorily solved.

Where an inventor has made a distinct advance in the coaling of warships he is at least entitled to further experiments, and if necessary even the largest of warships should be used in the carrying on of such experiments.

INCREASED COST AND DIFFICULTY OF PROCURING COAL.

The following extract from the report of the Chief of the Bureau of Equipment for the fiscal year ending June 30, 1900, strikingly shows the progressive increase in the cost of coal as well as the increased demand prevailing throughout the world.

"A total of 228,395 tons of coal, costing $1,572,652.97, at an average of $6.88 per ton, was purchased during the fiscal year.

"The following table indicates the amount of coal purchased for steaming purposes since 1892, with the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.		
1892	73,467	$550,451.35	$7.49
1893	67,054	449,065.27	6.69
1894	94,336	640,355.96	6.78
1895	98 615	527,590.25	5.35
1896	116,903	620,131.38	5.30
1897	138,318	655,921.72	4.75
1898	452,551	2,122,005.28	4.68
1899	281,169	1,679,510.55	5.97
1900	228,395	1,572,652.97	6.88

"Of the total amount of coal purchased, viz: 228,395 tons, 141,921 tons, costing, with the transportation thereof, the sum of $834,527.34, at an average of $5.88 per ton, were purchased at home.

"The following table indicates the amount of coal purchased at home for steaming purposes since 1892, with the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.		
1892	38,450	$221,918.66	$5.77
1893	33,257	147,999.04	4.45
1894	42,190	178,163.58	4.22
1895	50,630	181,985.89	3.59
1896	55,162	196,795.40	3.57
1897	82,051	280,091.09	3.41
1898	378,437	1,520,119.75	4.02
1899	195,216	1,238,355.40	6.34
1900	141,921	834,527.34	5.88

"The balance of the 228,395 tons, viz: 86,476 tons, were purchased by ships, costing the sum of $738,125.63, at an average of $8.53½ per ton.

"The following table indicates the amount of coal purchased by ships for steaming purposes since 1892, with the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.		
1892	35,017	$298,948.55	$8.53
1893	33,797	301,066.23	8.91
1894	52,146	462,192.38	8.86
1895	47,985	336,183.47	7.00
1896	61,741	423,335.98	6.85
1897	56,268	375,840.63	6.68
1898	74,111	601,885.53	8.12
1899	85,953	441,155.15	5.13
1900	86,476	738,125.63	8.53½

"It will be seen by examining the tables herewith that the amount of coal consumed by the Navy is increasing year by year. It was to be expected that there would be a large consumption

during the fiscal year 1898, on account of the Spanish war. As war operations had not entirely concluded on June 30, 1898, it was further to be expected that there would be an unusual expenditure in a less degree for the year 1899. The expenditure for the past year, however, is only about 53,000 tons less than for the year 1899; it is also only 26,000 tons less than the combined expenditures during the fiscal years 1896 and 1897, while the cost is about $300,000 more.

"The cost of coal is nearly $1 per ton greater than during the fiscal year of 1899, and more than $2 per ton greater than during the fiscal year 1898. The amount expended for coal and the transportation of the same during the last fiscal year is $250,000 greater than the entire appropriation for the Bureau during the fiscal year 1897.

"There has been during the past year almost a coal panic in the markets of the world, with a consequence that the prices have increased about 50 per cent. Until the 1st of April, 1900, the Bureau was able to purchase Pocahontas coal f. o. b. at Norfolk for $1.60 per ton. On that date the price was raised to $2.50 per ton, and continues at that rate. The above statement concerning Pocahontas coal applies equally to New River coal at Newport News. Pennsylvania coal was purchased at New York, delivered alongside, during the Spanish war for $1.75 per ton; it is now $2.85 per ton. Georges Creek coal, until the 1st of April last, was purchased at Baltimore f. o. b. at $1.60 per ton; it is now $2.43 per ton. The above-mentioned prices have been established by the Bituminous Coal Trade Association and are fixed.

"As a further indication of the advance in the cost of coal, the following table gives the prices for the best Welsh coal f. o. b. at Cardiff, Wales, from May, 1899, to date. By consulting this table it will be observed that the price has practically doubled during the past year. It is reported that the British Admiralty paid from $7 to $7.50 per ton for a portion of a recent order of 250,000 tons, and that this price was greater than ever before paid:

PRICES OF BEST CARDIFF COAL AT CARDIFF, WALES.

Date.	Price per ton.	Date.	Price per ton.
1899.		1900.	
May	$3.12 to $3.24	January	$6.48 to $7.20
June	3.12	February	5.76 to 6.00
July	1.12 to 3.18	March	5.40 to 5.76
August	3.12 to 3.24	April	5.04 to 5.52
September	3.12 to 3.24	May	5 28 to 5.64
October	3.18 to 3.36	June	5.28 to 5.52
November	3.30 to 3.42	July	5.28 to 5.52
December	4.80 to 5.04	August	5.76 to 6.00
		September	6.48 to 6.96
		October	6.12 to 6.48

THE NAVY'S DEMAND FOR COAL.

One of the prize essayists of the Royal United Service Institution of Great Britain writes thus:

"Coal, or the want of it, is the life or death of a fleet. The want of it was Cervera's undoing. Had he had coal he would never have been caught like a rat in a hole."

It was very apparent to naval experts that Admiral Cervera was done for when it became evident that the Spanish fleet had reached Martinique with depleted bunkers and with no reserve coal collected for the ships. Admiral Schley could well say that "the Spanish fleet would never get home again," as he contemplated its failure to get coal at Martinique, its desperate journey to Curacoa in the hope of filling bunkers, and the final flight for temporary safety to the bottle-shaped harbor of Santiago. It seems incredible that the admiralty officials at Madrid could have sent a fleet across the western ocean without providing a reserve supply of coal at some appointed base.

In the career of all admirals who command squadrons there comes some startling revelation of the necessary consumption, or excessive waste, if you will, of the bunker supply of the modern battleship. Such an experience was probably gained by the commander-in-chief of the British blue fleet in the naval maneuvers of 1899, when his squadron, which only steamed a couple hundred of miles to the westward of Ireland, consumed 31,000 tons during mobilization.

The matter must also have been brought very forcibly to the Lords of the Admiralty when they submitted an estimate for this year of practically £1,100,000 for the purchase of coal for the steam vessels and dock yards of the British navy. The Parliament may have had its surprise on the coal question when it was reported to this body "that an unforeseen and exceptional expenditure for coal of £350,000, for which otherwise a supplementary estimate would have been necessary, had, with the consent of the Treasury, been defrayed out of the unspent balance of the contract for new work."

Within a year or two it is exceedingly probable that the cost of coal for the British navy will approximate the estimate of the sum which will be required "to defray the expenses of naval and marine pensions, gratuities, and compassionate allowances" of the entire British service.

THE NAVY SHOULD PROVIDE AGAINST A COAL FAMINE.

The experience of the past year shows that a coal famine can be easily produced. Coal is a very bulky article, and therefore not only a large number of cars, but extensive piers and expensive machinery are required to move it. It is an expensive undertaking to increase the facilities for transporting coal, and railroad officials will not countenance the outlay, since it is not a profitable class of freight to handle. It has recently been asserted by one of the largest coal dealers in this country that it was practically impossible to collect or store a supply of coal that would meet the country's requirements for a month. A general strike of the miners in any extensive coal region would therefore soon produce a famine. With each succeeding year the control of its output is getting into the hands of fewer men, and they are going to demand greater profit than has heretofore been secured.

During the past twenty years there has been a very bitter competition carried on between the several corporations that have controlled the output of the various districts. This competition has been so keen between the districts that mining and carrying companies have had to combine to prevent a shut-

down in the territories controlled by them. Nearly every coal carrying railroad in the country has been in the hands of a receiver, and this shows how profitable the business has been.

From this time forward it can be expected that revenues will be received from both the mining and the carrying of coal, since the demand for fuel is now so great that the coal companies will almost be in condition to exact the terms and price under which they will supply their product. Upon this point Admiral Bradford writes:

"The only way the Government can be sure of sufficient good coal for its ships and rapidly supplying it is to have its own depots well stocked and furnished with all appliances necessary for transferring the coal to ships. If anything was proved during the Spanish war it was the fact that the Navy could not rely upon commercial firms for this service. As an illustration: Pocahontas coal is preferred by naval officials to any other kind in this country, yet to-day there is not a ton of that coal for sale in the great port of New York. This is owing to various business combinations of large magnitude for the purpose of promoting trade in other coal more profitable to those who control transportation."

Coal must, therefore, not only be kept in stock, but every device for reducing its consumption and increasing its handling and transportation facilities must be adopted by the service. Even if the vessels should all lie at anchor, there would be a heavy coal consumption, since three-fifths of that consumed by warships in commission is required for the auxiliaries.

COAL CONSUMPTION OF SOME TRANSATLANTIC STEAMERS.

	Displacement.	Indicated horse-power.	Highest average speed.	Average daily coal consumption.	Highest daily run.
	Tons.		*Knots.*	*Tons.*	
Oceanic	28,000	28,000	20.48 per trip...	480	524
Deutschland	23,000	35,000	23.36 per trip...	570	584
Kaiser Wilhelm der Grosse	20,000	28,000	22.79 per day...	500	580
Lucania	19,000	30,000	22.01 per trip...	475	562
St. Paul	11,600	20,000	21.78 per day...	300	540

There was a time when the Navy was one of the best of the coal customers. This is no longer the case, for there are worse ocean coal gluttons traversing the ocean than the warships. The data on the opposite page may give some idea of the demand of some other consumers.

With naval reserve vessels daily consuming such amounts of coal, it becomes imperative that the Navy should never run any risks of being without an heavy reserve storage.

COALING QUESTION GROWING IN IMPORTANCE.

This coaling question grows in importance as the subject is carefully considered. It concerns the Navy too much to be ignored, and therefore the sooner the question is met the better it will be for the interests of the service. The fact must be apparent that we are weak in coaling facilities on many vessels. If necessary, therefore, large expenditures should be authorized to make desirable changes. This may be a troublesome question, and yet as one beholds the great strength of the British navy and studies its past history, he is impressed with the fact that one of the causes which has produced its predominance has been the moral courage of its administrators in meeting rather than avoiding troublesome questions.

It was not many years ago that we failed to understand the importance of a rapid supply of ammunition to the guns. At that time any opening was considered good enough to be used for the raising of ammunition. Now the location, size and character of the ammunition passageways and elevators are regarded as of vital importance, for the efficiency of the gun may be seriously impaired by any failure to rapidly deliver shell. It required determined work upon the part of the ordnance experts to bring about this improvement. The resulting gain, however, has been very great. Why cannot equally good results be expected from a persistent and determined effort to improve our coaling arrangements?

Fortunately for the efficiency of the service, the coaling question is going to be met. There is not a writer of prominence upon naval affairs who does not call attention to its supreme im-

portance. Less than a month ago an important contribution to present-day criticism of the British navy was made by Admiral Sir J. O. Hopkins, G. C. B., in a paper which he read before the members of the Royal United Service Institution, entitled "*A Few Naval Ideas for the Coming Century.*" Amongst the measures mentioned by the Admiral as a test of the resources of the British fleet, he suggested that the Reserve squadron and mobilized ships put to sea for a fortnight's cruise, returning to a home port to fill up with coal as speedily as possible, carefully noting all weakness in its supply. He also recommended that the Channel and Mediterranean fleets be ordered to Gibraltar with all dispatch; there let them fill up with coal, noting any shortcomings. It was then his belief that the combined fleet should cruise on the Atlantic for a month, on return to Gibraltar the bunkers to be refilled with coal as speedily as possible and any shortcomings noted. It was evidently the opinion of Admiral Hopkins that the coaling facilities of the Reserve, Channel or Mediterranean squadrons were not satisfactory for cruising conditions. At the request of Vice Admiral Sir Harry Rawson of the Channel Squadron the British Admiralty have contracted for a *Miller Marine Cableway* to be fitted to the collier *Muriel*, and most exhaustive trials will be made to determine its efficiency to enable a squadron to keep to sea.

In the solution of this coaling question, primary consideration must be given to the location, size and character of the bunkers, and it should be realized that getting a sufficient supply to the fire room is only a little less important than getting the coal into the bunkers.

In the consideration of this question, the greater tendency has been to provide for the reception of coal on the deck of the warship. There has been neither too much time nor money expended in improving matters there, and it is even regrettable that increased opportunities to improve matters in this respect have not been given our commanding officers. It is more important still, however, that changes be made in the warship itself. If for a time improvements in the bunker arrangements can be considered as the most important phase of this question,

then we shall meet with a degree of success in coaling ship that will make the evolution less unpleasant and much more satisfactory. And while effecting improvements on board the warship, we should look to the question of securing colliers and barges that would answer our requirements. Particularly in this respect should we test and secure control of those appliances which are a distinct advance over anything of like nature that is possessed by others.

A COALING BOARD SHOULD BE APPOINTED.

This subject will only be accorded the consideration that it merits, when a board of officers of high rank shall carefully consider the matter in all its bearings. There is not a bureau chief at the Navy Department whose time is not already taken up, and therefore, this work should be carried on by a special board presided over by some senior officer who has commanded warships of various descriptions, and who by experience knows of the discomfort, difficulties and demoralization attending the coaling of warships.

However distinguished, able and competent an individual may be to give expression of opinion upon technical matters, it is a fact that individual views and recommendations never carry the weight that goes with the deliberate report submitted by a board of experts. The report of a board implies a concensus of views, of at least a majority of the members, and such a conclusion is founded after free discussion which is sure to have shown up the various phases of the matter.

If the report of a board is often a compromise, it generally commands increased support for that reason. It certainly obliterates all the extreme views and prejudices of the individual. One has only to recall to mind, the work of the several Advisory Boards, the Ordnance Board, the Armor Plant Board and the present Construction Board, to note the thoroughness with which such boards have entered upon their duties. And with this experience it can be confidently expected that an inestimable benefit would accrue to the Navy from the deliberations and conclusions of some future Coaling Board.

THE STEAMING RADIUS OF UNITED STATES NAVAL VESSELS.

By Lieutenant B. C. Bryan, U. S. Navy.

The question of how far a vessel may be expected to steam at different rates of speed under usual conditions is a very important one; in fact, it is of vital importance in time of war, and particularly so to a country like the United States, having few coaling stations, and these far from the base of any likely offensive operations.

In October, 1892, Passed Assistant Engineer Ira N. Hollis, U. S. Navy (now Professor of Engineering at Harvard University), delivered a lecture before the Naval War College on this subject, and gave endurance tables of the ships then forming the new Navy. This lecture and the tables were published in the Journal, Vol. 4, No. 4. It is the object of this article to give like data for as many vessels as possible, taking the longest runs recorded in the steam logs of such vessels, and runs at as many different speeds as are therein recorded for sufficiently long periods.

Attention is called to the fact that the necessities of the naval service require more auxiliary machinery than is usually required in the merchant marine, and also more than was formerly required on the old naval vessels, and as such machinery is usually wasteful in the use of steam, the coaling radius of a vessel will often depend upon the amount of such machinery in use.

It will also be found that on account of poor coal, the conditions of the sea and weather, difference in displacement, or foul bottom, or perhaps the condition of the boilers, leaks in piping, or for other reasons, anomalous conditions will appear in the different runs of almost every vessel. Some of these differences it seems impossible to account for, but the results are given in

order that it may be seen exactly what has occurred in the past on such vessels, and the reader may draw his own conclusions therefrom, so as to always be upon the safe side in estimating the probable steaming radius of such vessels.

It is much to be regretted that sufficient appropriation has never been allowed, nor opportunity offered the Bureau of Steam Engineering to carry out extensive tests on our vessels to ascertain the amount of water evaporated by the boilers per pound of coal under the various conditions incident to the service, and the amount of water used by the main engines and the different auxiliary engines at the same time. Such tests would undoubtedly point out the most economical use of boiler units for a desired speed, and also the most economical speed of each vessel. Further, it is believed by the writer that such experiments would lead to changes in the machinery, perhaps in the division of power of the main engine, and certainly in the arrangement of auxiliary machinery, that would tend to greater economy at low speeds and thereby not only save to the Government in a short time many times the cost of the experiments in saving of coal, but also, and vastly more important, in time of war, our vessels might be given a much larger steaming radius.

The Engineer-in-Chief of the Navy, in his report for 1900, asked for a modest appropriation, part of which was to be used in making such experiments, and it is hoped that facilities will be afforded him for this purpose.

To understand the conditions pertaining in the naval service, it must be remembered that the cruising power of our faster vessels usually varies at from one-eighth to one-tenth of the maximum power. Take, for example, a battleship of the *Pennsylvania* class, having a designed speed of 19 knots with 19,000 I.H.P., or an armored cruiser of the *Georgia* class, having a designed speed of 22 knots with 23,000 I.H.P.; these vessels cruising in a squadron at 10 knots would require about 2,400 I.H.P. and 2,200 I.H.P. respectively, or about one-eighth and one-tenth of their respective maximum powers.

No proper series of experiments have ever been carried out by our Government on our naval vessels to ascertain the exact

amount of water per hour used by the main engines and auxiliary engines under these circumstances. It is probable, however, that the main engines use slightly more steam per I.H.P. at this power than at higher powers, and that the auxiliary engines use vastly more.

Experiments were made upon the U. S. S. *Minneapolis* by Passed Assistant Engineer W. W. White, U. S. Navy, and read by him before a meeting of this Society, for which he received the prize for 1897. I believe these experiments to be the most extensive of their kind upon a naval vessel ever published. (See JOURNAL, Vol. X, No. 1.)

Other experiments were made upon the freight steamer *Pennsylvania* on the Great Lakes by Mr. White and the writer, in 1899, and published in the JOURNAL, Vol. XI, No. 3. Experiments have also been made on some English naval vessels, but sufficient data are not at hand, and, with the exception of the engines of the *Minneapolis*, the type of machinery is so different from that of our naval vessels that definite conclusions cannot be formed.

These tests, however, show that much economy can be gained by exhausting a certain amount of the auxiliary machinery into the feed heater, and that the auxiliary machinery at least, at low powers, is exceedingly extravagant in the consumption of steam. However, in spite of our lack of experimental data on these important subjects, it is believed that the actual coal endurance of *our* naval vessels will compare favorably with those of other nations.

The data in the following table is copied direct from the steam logs of the vessels named.

Column 1 gives the name and type of vessel.

Column 2 gives the full load of displacement as taken from the report of the Chief of Bureau of Construction and Repair. Where full load displacements are not obtainable data is marked to show this. n = normal displacement or displacement fully equipped ready for sea, all stores on board and normal coal supply. e = estimated displacement. t = trial displacement, all in tons.

Column 3 gives the type of engines.

Column 4 gives the type of boilers.

Column 5 gives the capacity of bunkers in tons of 43.5 cubic feet.

Column 6 gives the date of trip for reference, and also to show, in conjunction with columns 16 and 18, the probable condition of the bottom.

Column 7 gives the length of the run from which the data were taken. On each trip sufficient time was allowed at each end to be sure that the stopping, slowing, &c., incident to leaving and entering harbor would have no effect on the data. In the larger vessels from twelve to twenty-four hours at each end of a trip were omitted.

Column 8 gives the average speed by log, in knots, for the time during which other data were taken.

Columns 9, 10 and 11 give the knots run per ton of coal, the coal endurance in days and knots, respectively, based on the amount of coal actually used during the time data were taken. This amount of coal was as recorded in the steam log and as corrected therein for difference in coal account when such correction was necessary.

Columns 12 and 13 give the direction and force of the wind as usually marked in the deck logs of our naval vessels. In column 12, the numbers denote the direction of the wind in points of compass from dead ahead. V = variable. In column 13, 0 denotes a calm and 12 a hurricane, intermediate numbers denote the force on this scale.

Columns 14 and 15 give the direction and force of the sea. F = ahead, B = on bow, Q = on quarter, S = smooth, G = gentle swell, H = heavy swell, M = moderate sea, R = rough sea.

Column 16 gives the number of months that had elapsed since the vessel was last docked.

Column 17 gives the kind and quality of coal.

Column 18 gives the cruising ground.

Column 19 gives any recorded data that it is thought have a bearing on the result.

TABLE SHOWING STEAMING RADIUS OF U. S. NAVAL VESSELS.

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 2240 lbs.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Albany..... Sheathed protected cruiser.	4,011	Vert., triple ex., twin screw.	Scotch.....	747	June 9–11,'00.....	31.75	12 7	6.5	15.9	485
					June 26–30,'00.....	95.7	12.3	8.2	20.8	616
					July 26–30,'00.....	95.5	11.7	6 9	18.3	519
					Sep. 11–14,'00.....	73.3	10.4	5.3	15.6	383
Amphitrite..... Monitor.	3,990	Inclined, comp., twin screw.	Scotch.....	264	Jan. 1, 2,'96.....	48	6.92	4.96	7.9	139
					Jan. 7–9,'96.....	63.5	7.69	5.75	8.2	151
					June 10–12,'96.....	60	6.2	4.58	8.1	129
					Mar. 11,'97.....	6	10 72	4.29	6.2	133
					May 5, 6,'97.....	28	8.19	5.01	6.7	132
					Oct. 6, 7,'97.....	41	7.58	6 65	9.6	175
					Mar. 10–12,'99.....	49.86	9.79	5.57	6.25	147
Annapolis..... Composite gunboat.	1,116	Vert., triple ex., single screw.	Babcock & Wilcox.....	222	Sep. 9–12,'97.....	96.5	8.94	23.18	24	514
					Nov. 9–11,'97.....	71 4	9.57	26.38	25.4	569
					Apr. 19–24,'98.....	144.4	8.69	20.62	21.9	457
					Aug. 25–Sep. 4,'98....	257.3	8.2	26.97	30.4	594
Arethusa..... Tank steamer.	6,200	..... Do.....	Scotch.....	685	Dec. 20–22,'98.....	72	8.99	9.73	30.8	665
					Jan. 15–17,'99.....	71	10.64	10.76	28 8	737
Atlanta..... Protected cruiser.	3,180	Hor., comp., single screw.	Scotch.....	473	Dec.,'89.....	288	8.53	6.53	15	308
					June,'90.....	216	8.4	8.04	18.8	389
					July,'90.....	336	8.71	7.71	17.5	364
					July,'90.....	144	10.1	7.10	13.9	335
	3,180	Hor., triple ex., single screw.	Part Scotch, part Babcock & Wilcox.	567	Nov. 10, 11,'00.....	24	11.04	6 51	13.93	369
Baltimore..... Protected cruiser.	5,436	Hor., triple ex., twin screw.	Scotch.....	1143	Aug. 23–Sep. 12,'90..	468	10	5.32	25.4	608
					Oct. 18–23,'90.....	121.4	13	4.33	16.3	494
					Mar. 2–12,'91.....	265.3	11.3	5.72	24.2	653
					Dec.20,'91–Jan 3,'92.	362.7	9 45	5.56	28	823
					Jan. 24–Feb. 11,'93...	456	8 51	4.74	36.5	541
					Sep. 16–Oct. 1,'93....	352.7	10.07	6.31	29 8	721
					Nov. 9–23,'93.....	333	9.48	5.72	28.6	653
					Jan. 10–18,'96.....	192	10.8	3.64	16	416
					Mar., Apr., '98.....	338.3	9.1	4.33	22 7	495
Bancroft..... Gunboat.	943	Vert., triple ex., twin screw.	Cyl., straightway, fire-tube.	139	Sep.,'96.....	238	9	21.16	13.6	294
					July,'97.....	72.6	6 9	12.21	10.2	107
					Mar.,'98.....	95.4	10.01	22.8	13.2	310
					Mar.,'98.....	96.4	9.57	19.54	11.8	271
Bennington..... Gunboat.	1,764	Hor., triple ex., twin screw.	Cyl., straightway, fire-tube.	391	Mar.,'96.....	240	8.08	7 38	14.9	288
					May,'97.....	193	8 23	6.66	13.1	260
					Aug.,'97.....	194.3	10.54	7.88	12.1	308
					Sep.,'98.....	169 7	9.33	8	14	312
					Jan.,'99.....	353	9.3	11.1	20	440
Boston..... Protected cruiser.	3,195	Hor., 3-cylin., comp., single screw.	Scotch.....	480	July,'90..	356	8.91	8 2	18.4	393
					Mar.,'92.....	96	11.3	6.08	10.8	292
					May,'97.....	80.8	12.62	6.90	10.9	331
					Mar.,'98.....	72.7	13.78	6.88	10	330
					Dec.'98.....	84	12.56	7.54	12	361
Brooklyn..... Armored cruiser.	9,797	Vert., triple ex., twin screw. 2 engines to each screw.	Scotch.....	1460	July,'97.....	262 7	12.09	3 34	16.72	487
					Aug.,'98.....	96	9.28	3.2	21	467
					Oct ,'99.....	281	12.22	3.54	17.5	510

[NOTE.—For explanation of reference letters, see pp. 52, 53.

COMPILED FROM DATA OF ACTUAL RUNS, AS SHOWN BY STEAM LOGS.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
V	3-4	S	S	...	West Hartley Main, best screened	River Tyne to Southampton..	
V	2	S	S	...	Best Welsh	Southampton to Gibraltar....	Draught, 17 ft. 1½ ins.
V	2	S	S	...	Best Welsh and Hartley Main....	Gibraltar to Malta	Draught, 16 ft. 7 ins.
V	2	S	S	...	Nixon's Navigation	Naples to Piraeus	Draught, 18 ft. 8 ins.
V	3	B	M	2	Bituminous	North Atlantic	
V	2	S	S	2½	Pocahontas, good	Do	
V	3	S	S	8	Bituminous	Do	
o	4	F	M	3	Pocahontas, good	Do	Full-power trial.
13	3	S	S	5	Clearfield, poor	Do	
4	4	M	S	½	Bituminous	Do	
?	?	?	?	3½	Do	Do	
?	3	?	SM	5	Do.	Do	Fore and aft sail set 60 p. c. time.
?	4	?	RM	7	Anthra., 1 day, Bit., 2 days, fair..	Do	Sail to topsails 91 per cent. time.
o	4	V	MS	42	Bituminous	Do	Fore and aft sail set 42 p. c. time.
8	2	S	S	16	Pocahontas, good	Do	Fore and aft sail set 50 p. c. time.
2	3	S	M	4	Bituminous, good	Do	
6	4	S	M	5	Do	Do	
8	3-4	FBQ	RM	1¼	Anthracite	Do	Sail set 85 per cent. time.
4	2	S	S	1½	Bituminous, good	South Atlantic	
8	3	S	S	2½	Do	Do	
10	3	S	S	3	Do	South and North Atlantic	
o	3	F	M	...	Eureka, fair	North Atlantic	B. and W. boilers in use.
o	3	S	S	4½	Bituminous	Do	
8	4	Q	M	½	Cardiff	Copenhagen to Lisbon	
6	2	B	G	¾	Do	North and South Atlantic	
8	2	S	S	10	Cardiff, good	Pacific	
8	3	B	G	5	Do	South Atlantic	
9	3	S	S	1	Victor, good	N. At. and Mediterranean	
6	3	B	G	2¾	Cardiff, fair	Red Sea and Indian Ocean	
13	4	B	MH	8	Departure Bay, bituminous	Pacific Ocean	Heavy seas.
...	4	...	MS	6	Cumberland, good	Do	
10	3	B	SM	½	Eureka, good	North Atlantic	Fore and aft sail set 30 p. c. time.
1	3	F	MS	3	Prince brand briquettes, v. poor	Mediterranean	
9	3	...	HMS	3½	Lewis Merthyr, good	North Atlantic	Fore and aft sail set 66 p. c. time.
6	4	...	SM	½	Bituminous	Do	Fore and aft sail set 20 p. c. time.
7	4	S	S	11	Wellington, Westminster, g. to f..	Pacific	Bottom very foul.
2	3	S	MG	5½	Australian, New Castle, mixed	Do	
10	3	S	M	1	Bituminous, mixed	Do	Fore and aft sail set 54 p. c. time.
5	3	S	S	2½	Mixed bituminous, good	Do	
12	3	S	S	6	Pocahontas	Do	
Wind always favorable				3	Bituminous, good	Rio de Janeiro to St. Lucia...	Sail set 81 per cent. time.
10	3	B	G	2½			
4	3	B	S	½	Cardiff, good	China Seas	
13	5	Q	M	2⅔	Do	Do	
9	5	BQ	MS	3⅓	Do	Do	
4	3	F	SM	3	Powell-Duffryn, good	North Atlantic	
4	4	F	SM	8	Pocahontas, Cumberland, good	Cuban waters	
1½	2-3	F	SM	4	Bituminous	North Atlantic	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 35 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Buffalo...t..... Converted cruiser.	6,888	Vert., triple ex., single screw.	Scotch.....	1355	Dec., '98	436.4	12.2	6.24	29.75	8705
					Apr., '99.....	355.8	13.97	4.72	19.6	6584
					May, '00.....	257	8.34	6.91	48.8	9362
					June, '00.....	114 75	11.11	4.77	24 27	6483
Cassius..... Collier.	6,800	Vert., comp., single screw.	Scotch.....	900	Oct., Nov. '98.....	477.5	8.3	6.16	27.8	5544
					Nov., '98.....	241	9.48	9.21	36.4	8249
Castine..... Gunboat.	1,318	Vert., triple ex., twin screw.	Gunboat locomotive.....	290	Feb., '95	237	9.075	14.2	19	4119
					Sep., '95.....	174.4	9.25	13.45	17.6	3900
					Nov., '96.....	166.5	10.0	17.27	20.8	5008
					Apr., '97.....	262.4	9.24	13.58	17.7	3938
					Jan , '99	238.3	9.55	11.37	13.48	3091
					Mar., '99.....	289 6	7.18	10.16	15.34	2641
Celtic ..... Supply vessel.	8,000	Vert., triple ex., single screw.	Scotch.....	760	Oct., '98.....	425	9.64	7.55	24.8	5738
					Dec., '98.....	120	9.08	11.52	40.2	8755
					Mar., '99	591	8.4	8.2	30.3	6233
					June, '99.....	456	8.1	7	27.4	5320
Chicago..... Protected cruiser.	5,273	Hor., triple ex., twin screw.	Part Babcock & Wilcox, part Scotch.	889.4	Mar., '99.....	88	12.4	4.1	12.21	3646
					Mar., '99.....	72	12.8	4.3	12.4	3824
					Aug., '99.....	120	10.5	4.7	16.5	4180
					Sept., '99.....	240	11.3	4.5	14.9	4008
					May, '99.....	144	11 3	4.6	15.11	4090
					June, '99.....	168	10.2	3.76	13.58	3334
Cincinnati..... Protected cruiser.	3,562	Vert., triple ex., twin screw.	Scotch.....	480	Aug., '95.....	123	10.77	5.25	9.7	2520
					Sep., '96.....	225	9 36	6.16	13.2	2957
					Oct., '96.....	176	9.53	5.51	11.5	2645
					Apr., '97.....	143.6	10.6	5.65	10.6	2711
					June, '97.....	121.4	10.45	6.66	12.7	3196
					July, '97.....	170	9.25	5.49	11.8	2633
					Feb., '98.....	117.5	11.87	5.46	9.2	2620
Columbia..... Protected cruiser.	8,442	Vert., triple ex., three screws.	Scotch.....	1600	Mar., '95.....	96	14.98	3.13	14	5010
					May, '95.....	209	16.3	2.71	11.11	4345
					Aug., '95.....	167.8	18.41	2.09	7 55	3349
					Aug., '95.....	49.25	19.36	2.02	6.96	3233
					June, '98.....	72.23	15.31	2.91	12.6	4656
					Aug., '98.....	97	12.24	2.50	13.6	4000
Concord..... Gunboat.	1,815	Hor. triple ex., twin screw.	Cyl., straightway, fire-tube.	380	Apr., '96.....	408	7.8	10.1	20.6	3881
					Nov., '97.....	48	10 65	10.6	15.8	4026
					Jan., '98.....	194	9.64	11.6	19.1	4408
					Feb , '98.....	388.4	8.49	11.75	21.9	4465
Culgoa..... Supply vessel.	6,500e	Vert., triple ex., single screw.	Scotch.....	913	Apr., '00.....	99	11	7.37	25.3	6721
					Apr., '00.....	159	10 5	7.69	27.9	7017
					June, '00.....	169	10.9	7.9	27.5	7209
Cushing..... Torpedo boat.	142.5	Vert., quad. ex., twin screw.	Thornycroft.....	39	Sep., '97.....	8	18	18	1.6	701
					Oct., '97.....	10	14	28	3¼	1092
					Oct., '97.....	11.5	15.5	20.7	2½	806
					Nov., '97.....	27	15 5	24.8	2⅞	901
					Jan., '98.....	17	13.46	20.8	2.5	811
					Jan., '98.....	19	13.4	20.4	2.4	797
Detroit..... Unprotected cruiser.	2,235	Vert., triple ex., twin screw.	Scotch.....	352	Oct., '93.....	238.7	10.78	9.73	13.9	3425
					Apr., '94.....	290	7.95	8.12	15.0	2858
					Nov., '94.....	213	9.55	10.13	15.5	3565
					Feb., '95.....	142 5	10.24	9.42	13.4	3315
					Feb , '95.....	6	13.85	8.79	9.3	3094

NOTE.—For explanation of reference letters, see pp. 52, 53.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
...	...	...	...	4	Pocahontas, good	Norfolk to Port Said	
...	...	...	...	...	Do	Do	
V	1–6	S	S	2	Do	North Atlantic	
V	2–4	S	S	3	Welsh, poor	Gibraltar to Gravesend	
5	4	M	M	1	Bituminous	North and South Atlantic	Fore and aft sail 60 p.c. time.
8	3	S	M	2	Do	Do	Fore and aft sail 43 p.c. time.
12	5	BQ	MR	3	Clearfield	North Atlantic	Fore and aft sail 64 p.c. time.
13	3	Q	G	2	Ocean Merthyr	South Atlantic	Fore and aft sail 50 p.c. time.
8	4	B	M	1	Pocahontas, fair	North Atlantic	Fore and aft sail 76 p.c. time.
4	4	FB	M	1	Do	North and South Atlantic	Fore and aft sail 58 p.c. time.
8–15	3	B	SH	3½	Do	San Juan to Punta del Gada	
5	1–5	FB	SM	5½	Ferndale, Cardiff	Aden to Colombo	
Generally favorable				½	Bituminous	North and South Atlantic	
Generally favorable				2⅔	Do	South Atlantic	
...	...	...	...	5	Do	Honolulu to Manila	
...	...	...	...	6	Do	Manila to Sydney	
1–2	2–8	F	S	4	Georges Creek, Pocahontas	North Atlantic	
6	3	B	M	4	Pocahontas	Do	
...	...	...	...	...	Cary Bros'. Merthyr		
...	...	...	...	2	Pocahontas		
...	...	...	...	6	Cardiff		
...	...	...	...	7	Cardiff, very poor		
3	2	...	SG	½	Bituminous, poor	North Atlantic	
6	4	B	S	1¾	Do	Do	
3	2	S	S	2½	Do	Mediterranean	
7	2	Q	S	1	Cory's Merthyr, good	Do	
8	3	Q	S	3	Bituminous, good	Do	
5	4	Q	S	3½	Bituminous, fair	North Atlantic	
3	4	B	M	0	Ocean Merthyr, good	North and South Atlantic	
5	2	F	G	¼	Bituminous	New York to Jamaica	
8	4	B	S	2½	Do	New York to England	
5	3	B	S	½	Do	Southampton to New York	
5	3	FQ	SM	¼	Do	North Atlantic	
4	3	BQ	SM	¼	Bituminous, good	Do	
4	3	BQ	M	2½	Eureka, fair	Do	
6	4	B	MS	5¾	Cardiff, Powell, Duffryn, good	Rivers of China and Pacific	Fore and aft sail 75 p.c. time.
7	2	S	S	8	Comox, good	North Pacific	Fore and aft sail.
10	4	B	MS	1	Comox and Cardiff, good	Do	Fore and aft sail 13 p.c. time.
8	4	BQ	MS	1½	Georges Creek, good	Do	Fore and aft sail 54 p.c. time.
7.7	2	S	S	5½	Bulli, fair	Asiatic Station	
6.6	2.2	S	S	5½	Various, poor to fair	Do	
3	2	S	S	8	Pocahontas, good	Do	
0	4	F	M	0	Bituminous, good	North Atlantic Station	
12	8	B	M	0	Pocahontas, fair	Do	
V	1	S	S	0	Do	Do	
V	3	S	S	1	Pocahontas, good	Do	
12	2	S	S	4	Empire, bad	Gulf of Mexico	
4	1	S	S	4	Do	Do	
4	3	B	SM	1½	Cardiff, fair	North and South Atlantic	
5	4	FB	GM	7	Ocean Merthyr, fair	South and North Atlantic	
6	4	BQ	MS	⅔	Pocahontas, good	North Atlantic	
8	2	B	S	4	Cardiff, fair	Indian Ocean	Fore and aft sail set.
6	3	B	SM	4½	Ferndale, good	China Sea	Full power, natural draft.

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 40 c. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Detroit.....	2,235	Vert., triple ex., twin screw.	Scotch.....	352	Feb., '96.....	3½	19.21	4.21	3.2	1481
Continued.....					Feb., '97	117.2	13.4	7.25	7.9	2552
					Mar., '97.....	127.7	12.34	8.9	10.5	3132
					Jan., '99.....	116	10.65	6.79	9.43	2410
Dixie.....	6,114	Vert., triple ex., single screw.	Scotch.....	1248	Aug., '98.....	70.6	13.93	4.77	17.8	5953
Auxiliary cruiser.										
Dolphin.....	1,486n	Vertical, comp., single screw.	Scotch.....	265	Jan., '89.....	266.3	9.01	13.4	16.5	3551
Despatch boat.					Feb., '89.....	434.8	8.23	12.8	17.2	3400
					Apr., '89.....	144.9	9.52	11.7	13.6	3100
					Jan., '97.....	36	12.6	10.7	9	2835
				256.2	Apr., 00.....	84	12.7	10.6	8.9	2715
Dupont.....	165n	Vert., triple ex., twin screw.	Modified, Normand.....	43	Oct., '97.....	13	20	16.2	1.45	697
Torpedo boat.					Oct., '97.....	8	14.9	23.8	2.87	1023
					Oct., '97	9	14.4	21.6	2.68	929
					Oct., '97.....	9	15	24.5	2.9	1054
					Nov., '97.....	27½	13.8	25.7	3.3	1105
					Nov., '97.....	8	15	20	2.38	860
					Dec., '97.....	6	17.2	22.9	2.38	985
					Dec., '97	12	14.5	29	3 58	1248
Ericsson	170	Vert., quad. ex., twin screw.	Thornycroft	40	Nov., '97.....	12	13.2	27	3.4	1008
Torpedo boat.					Dec., '97.....	12	14.3	24.6	2.85	984
					Feb., '97.....	49	11.6	33.5	4.8	1340
Foote	180	Vert., triple ex., twin screw.	Mosher	43	Sep., '97.....	29	12.4	26	3.4	1118
Torpedo boat.					Sep., '97.....	12	11.6	23.2	3.58	998
					Nov., '97.....	20	14.4	28.8	3.58	1238
					Nov., '97.....	10	14.2	28 4	3.58	1221
					Jan., '98.....	21	11.8	38	5.80	1634
					Mar., '98.....	34	13.1	26.2	3.58	1126
					Mar., '98.....	34	12.6	25.2	3.58	1084
					Mar., '98.....	10	9.0	22.5	4.4	967
					Aug., '98.....	47.5	9.6	21	4	903
					Aug., '98.....	39.4	12.6	25.4	3.6	1092
Glacier	7,000e	Vert., triple ex., single screw,	Scotch.....	942	Aug., '98.....	96	8.92	5.5	24.2	5180
Supply vessel.					June, '99	95.2	10.89	6.12	22.1	5765
Gloucester.....	786	Vert., triple ex., single screw.	Scotch.....	93	June, '98.....	8	13.5	14.4	4.1	1339
Converted yacht.					Sep., '98	10	12.2	13.5	4.3	1355
Gwin	58	Vert., triple ex., single screw.	Normand	8	July, '98	35	12	77.7	2.15	622
Torpedo boat.					Aug., '98.....	28	12.6	73.9	1.95	591
					Aug., '98.....	12	14	62.8	1.5	502
					June, '99.....	14	10	50	1.6	400
Hannibal.....	4,291	Vert., triple ex., single screw.	Scotch.....	275	July, '98.....	120	8.51	15.8	21.2	4345
Collier.					Sep., '98.....	72	7.33	16.1	25.1	4427
Helena.....	1,689	Vert., triple ex., twin screw.	Scotch.....	274	Aug., '97.....	168.7	8.56	11.61	15.4	3181
Gunboat.					Dec., '97.....	60.8	9.71	10.9	12.8	2986
					Jan., '98.....	285	7.96	10.34	14.7	2833
					Mar., '98.....	291.2	8.28	10.5	14.4	2877
					Nov., '98.....	285	7.84	10	14.6	2740
					Apr., '99	156	8.9	16.95	21 7	4645
Hist	472	Vertical, comp., single screw.	Scotch	54	July, '98.....	12	8.3	30.3	8.23	1636
Converted yacht.					Aug., '98.....	12	10.7	25.68	5.4	1386
					Jan., '99.....	68	8	20.00	5.6	1080

NOTE.—For explanation of references letter, see pp. 52, 53.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
15	4	Q	M	¼	Ferndale, good	Yellow Sea	Full power, forced draft.
12	5	Q	SM	4½	Do	China Sea	
5	3	S	S	5	Do	Indian Ocean	
...	...	...	...	2	Georges Creek	North Atlantic	
8	3	V	SM	4	Bituminous	West Indies	
10	3	BQ	MH	3	Do	North Pacific	Sail set 99 per cent. time.
6	2	F	G	3⅔	Bituminous and anthracite	Do	Sail set 45 per cent. time.
2	2	FB	G	6⅔	Ocean Merthyr, good	Indian Ocean	Sail set 20 per cent. time.
6	4	FB	MH	8	Bituminous	North Atlantic	
4.5	2–3	F	S	7¾	Argyle Mine, Bituminous	Quantico to Samana Bay	Sail set 33 per cent. time.
0	1–2	Q	S	⅙	Pocahontas	North Atlantic	
0	3	F	RM	⅙	Do	Do	
0	1–2	...	...	...	Do	Do	
0	3	...	...	...	Georges Creek	Do	
16	3	V	S	1	Pocahontas	Do	
0	3	F	S	1½	Do	Do	
16	3	Q	S	3	Georges Creek	Do	
16	3	Q	S	3	Do	Do	
8	3	B	MS	1	Pocahontas	Do	
11	3	Q	M	3	Georges Creek	Do	
9	3	B	M	0	Milldale	Do	
0	3	B	S	½	Pocahontas	Do	
4	5	F	M	¾	Do	Do	
0	2	S	S	1	Do	Do	
0	3	B	SM	1	Do	Do	
0	5	Q	G	3	Do	Do	
0	2	F	S	0	Pocahontas, good	Do	
0	2	F	S	0	Do	Do	
0	2	B	S	2	Do	Do	
12	3	Q	M	5	Do	Do	
12	3	Q	M	5	Do	Do	
V	4	V	SMR	2	Bituminous, fair	Do	
V	4	V	SMR	2	Dufferin, good	Do	
16	2	Q	G	1	Pocahontas, good	Do	
2	6	F	M	4	Do	Do	Foul bottom.
3	3	F	S	½	Do	Waters of Florida	
8	2	B	S	2	Do	Do	
0	3	F	S	2	Do	Do	
...	...	S	S	12	Pocahontas		
3	2	S	S	2	Bituminous	North Atlantic	
11	2	S	S	4	Do	Do	
6	3	S	S	6	Do	North Atlantic and Gulf	
12	4	...	M	0	Do	North Atlantic	
5	3	...	RMS	⅔	Do	Do	
5	4	...	RM	3⅓	Do	Do	
5	4	Rough		1½	Pocahontas, good	Do	
...	...	...	...	0	Bituminous	Singapore to Manila	
9	3	B	G	3	Pocahontas	Cuban waters	
2	3	F	M	3½	Do	Do	
6	2	B	G	9	Pocahontas, good	Do	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 42.5 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance	
									In days.	In knots.
1	2	3	4	5	6	7	8	9	10	11
Hornet Converted yacht	425	Vert., triple ex., single screw.	Scotch	65	Apr., '98	111	12	24.8	5.6	1612
					Aug., '98	44	8.2	21	6.9	1365
					Aug., '98	77	11	23.5	5.7	1527
Indiana Battleship.	11,403	Vert., triple ex., twin screw.	Scotch	1550	Aug., '98	96	9.17	2.24	16	3472
					Mar., '99	98.15	9.6	3.8	25 4	5872
					May, '99	135	10.15	3.22	20.6	5000
Iowa Battleship.	12,445	Vert., triple ex., twin screw.	Scotch	1600	May, '98	47 8	10.46	2.49	15.9	3984
					Aug., '98	96	8.92	2.66	20	4256
					Oct., '98	262	9.31	2.98	21.3	4768
					Dec., '98	120	9.28	2.94	21.1	4704
					Jan., '99	329	9.20	3.39	24.59	5424
Iris Distilling ship.	6,1000	Vert., comp., single screw.	Scotch	2475	Jan., '99	552	6.7	6	92.3	14850
Justin Collier.	3,300	Vert., triple ex., single screw.	Scotch	185	May, '98	24	8.4	15.85	14 5	2936
					June, '98	24	7.7	16.9	17	3196
					July, '98	96	10.1	20.4	15.6	3774
Katahdin Ram.	2,383	Hor., triple ex., twin screw.	Scotch	202	Mar., '97	21	9.14	5.35	4.9	1080
Machias Gunboat.	1,318	Vert., triple ex., twin screw.	Marine locomotive	290	June, '93	4	15.46	7.58	5.92	2198
					Dec., '94	261.1	9	15.64	21	4536
					Jan., '95	190	10.48	13.95	16.1	4045
					Dec., '97	144.75	9.65	14.49	18	4202
					Mar., '98	315	10.19	15.25	18	4422
					Jan., '99	161	8.39	16.3	22.5	4726
					Feb., '00	156.6	9.5	12.5	16	3625
Manila Transport.	1,750	Vert., comp., single screw.	Scotch	186	Sep., '99	61	8.63	10.64	10 2	1979
Marblehead Unprotected cruiser.	2,219	Vert., triple ex., twin screw.	Scotch	330	June, '94	95.2	10.8	8.45	10.7	2788
					Mar., '95	118 3	9.94	8.69	12	2867
					Mar., '95	71	11.11	8.06	10	2659
					Apr., '95	165.8	11.22	9.14	11.2	3016
					Sep., '96	118.8	10.12	8.99	12.2	2967
					Oct., '96	169.3	9.37	7.03	10.3	2320
					Nov., '96	242.2	9.06	7.97	12.1	2630
					Apr., '99	120	8.8	7.4	11.7	2442
Marietta Composite gunboat.	1,058	Vert., triple ex., twin screw.	Babcock & Wilcox	246	Mar., '98	120.4	8.36	12.61	15.4	3102
					Mar., '98	149.5	9.92	14.27	14.7	3510
					Apr., '98	155.6	10.04	13.57	13.8	3338
					Apr., '98	227.2	10.10	12.68	12.8	3119
					May, '98	170.9	7.89	16.6	21.5	4083
					Feb., '99	113	8.5	15.3	18.5	3774
Massachusetts Battleship.	11,403	Vert., triple ex., twin screw.	Scotch	1560	Feb., '97	43	9.95	2.47	16.1	3853
					June, '97	52.9	12.68	3.075	15.8	4797
					May, '98	99	10.67	2.942	17.9	4589
					Aug., '98	96	9.87	3.58	23.5	5584
					May, '99	120	9.9	3.8	25.5	6067
Mayflower Converted yacht.	2,690	Vert., triple ex , twin screw.	Scotch	510	Apr., '98	113.8	11.3	9.5	17 8	4845
Miantonomoh Monitor.	3,990	Inclined comp., twin screw.	Scotch	240	May, '98	70.3	6.85	4.81	7	1154
					Sep., '98	95.5	5.72	6	10.5	1442

NOTE.—For explanation of reference letters, see pp. 52, 53.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
...	...	...	...	...	Cumberland	North Atlantic	
...	...	...	...	...	Bituminous, fair.	Cuban waters.	
...	...	...	...	...	Do	North Atlantic	
8	3	BQ	MS	12	Bituminous, good	Waters of Cuba	
7	3	B	M	6	Do	North Atlantic	Steaming in fleet.
...	...	...	...	7	Pocahontas		
7	3	B	MS	13⅗	Bituminous, good	Waters of Florida	
8	3	V	S	16½	Pocahontas, good	Guantanamo to New York	
6	4	B	G	1	Bituminous	North Atlantic	
7	4	FB	GMR	3	Do	South At and South Pac	
...	...	...	...	5	Do	Pacific	
...	...	...	...	6	Pocahontas	Gallapagos to Hawaii	
..	...	...	...	1	Do	North Atlantic	
...	...	...	...	1	Do	Do	
3	2	...	MS	2	Do	Do	
12	5	BQ	MR	7	Bituminous	Do	
...	...	...	...	0	Pocahontas, selected	Do	Data of official speed trial.
8	4	B	M	1½	Clearfield, good	Do	Fore and aft sail 50 p.c. time.
5	3	S	S	3½	Ocean Merthyr, good	Indian Ocean	Fore and aft sail 40 p.c. time.
4	3	F	SM	5	Bituminous, good	Do	Fore and aft sail 41 p.c. time.
7	4	FBQ	MS	½	Cardiff, good	North Atlantic	Fore and aft sail 57 p.c. time.
6	3	F	G	3½	Bituminous, fair	Do	
8	3	B	M	4	Eureka and Clearfield, good	San Juan to Pensacola	
...	...	...	...	5	Georges Creek and Japanese	Philippine waters	
6	3	S	S	1½	Clearfield, good	North Atlantic	Fore and aft sail set.
10	4	Q	MH	1½	Picton and Pocahontas, good	Do	Fore and aft sail 75 p.c. time.
8	5	B	M	1⅖	Ferndale, good	Do	Fore and aft sail.
5	3	B	SR	2	Pocahon. and O. Merthyr, good	Mediterranean	Fore and aft sail 12 hours.
12	2	S	S	2	Nixon's Nav., good	Do	
7	2	B	G	3½	Nixon's Nav., fair	Do	
10	3	B	G	4	Mixture of Welch coal, poor	North Atlantic	
...	...	...	...	3½	Welsh	Do	
4	3	S	S	7	Australian, poor	North Pacific	Foul bottom.
3	2	S	M	7	Cumber. mixed with other, fair	North and South Pacific	Do.
2	2	M	S	8	Cardiff and Comox, fair	South Pacific	Do.
6	3	S	M	8	Welsh, good	South Atlantic	Do.
9	3	S	M	9	Cory's Merthyr, good	Do	Foul bot.; f. & a. sail 48 p.c. time.
...	...	...	...	...	Bituminous	North Atlantic	
9	2	B	S	21	Pardee, good	Do	Foul bottom.
10	3	BQ	SM	1½	Pocahontas, good	Do	
5	2	S	S	12	Do	Do	
9	3	S	M	14⅗	Do	Do	
...	...	...	...	1		Do	
...	3	S	S	0	Cumberland	Do	
...	2	...	S	20	Bituminous, good	Do	
V	3	...	SM	24	Do	Do	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 62.5 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Minneapolis..... Protected cruiser.	8,878	Vert., triple ex., three screws.	Scotch.....	1520	Mar., '95.....	147	14.3	2.81	12.5	4371
					Dec., '95.....	50	10.78	3.59	21	5437
					Apr., '96.....	53.5	9.16	4.27	29.5	6489
					May, '96.....	96	11.27	3.80	21.3	5776
					Oct., '96.....	71.5	10.46	4.66	28.2	7083
					Dec., '96.....	78.4	8.53	4.49	33.2	6814
					May, '97.....	4.55	20.16	0.735	2.31	1117
					June, '97.....	73.15	11	4.08	23.5	6201
					July, '97.....	352 4	9.72	4.20	27.4	6384
					May, '98.....	47.1	18.45	2.225	7.63	3382
Monadnock..... Monitor.	4,005*n*	Hor., triple ex., twin screw.	Scotch.....	386	July, '96.....	93	7.22	4.39	9.7	1679
					Jan., '97.....	19	10	7.69	12.3	2968
					Apr., '98.....	72	8.22	5.65	11	2181
					July, '98.....	218.2	8.768	7.23	13.2	2790
Monterey..... Monitor.	4,084*n*	Vert., triple ex., twin screw.	Part Ward, part Scotch.	220	May, '95.....	166.9	7.76	7.78	9.1	1711
					May, '93.....	167.8	7.348	7.60	9.4	1673
					May, '95.....	144	7.854	8.06	9.4	1773
					Aug., '95.....	145.1	8.05	6.84	7 7	1394
					Feb., '96.....	35.8	10.27	5.63	5	1138
					Mar., '96.....	69.3	10.03	6.52	5 9	1434
					Sep., '97.....	48	9.65	4.62	4.3	1016
					Dec., '97.....	45	10.18	5.97	5.3	1313
Montgomery..... Unprotected cruiser.	2,235	Vert., triple ex., twin screw.	Scotch.....	351	Nov., '94.....	149.3	12.32	8.68	10.3	3046
					May, '95.....	71.5	11.41	9.21	11.8	3332
					Sep., '95.....	24	9.42	9	14	3159
					Jan., '96.....	24	14.26	8.56	8.8	3004
					July, '96.....	96	10.73	8.44	11.5	2961
					Sep., '96.....	48	12.21	7.34	8.8	2576
					Aug., '97.....	143.1	9.15	7.24	11.5	2541
					Oct., '97.....	103.6	11.93	7.56	9.2	2653
Nashville..... Gunboat.	1,720	Vert , quad. ex., twin screw.	Part Yarrow, pt. Scotch	395	Oct., '97.....	48	7.67	8.1	17.3	3199
					Feb., '98.....	72 5	8.53	11.5	22.3	4542
					Feb , '98.....	48	10.06	13.34	21.8	5269
					Feb , '99.....	72	11.33	10.4	15.3	4180
					Jan., '99.....	108	7.35	9.3	19.6	3720
					Sep., '99.....	72	9.12	10.5	19.2	4200
Nero..... Collier.	4,925	Vert., triple ex., single screw.	Scotch.....	323	Dec., '98.....	737.3	6.917	10.85	21	3504
					May, '99.....	192	9.34	14.3	19.92	4619
Newark..... Protected cruiser.	4,592	Hor., triple ex., twin screw.	Scotch.....	790	Aug., '94.....	355	9.8	5.57	18.7	4400
					Oct., '94.....	108.9	11.43	7.27	20 9	5743
					Oct., '94.....	204	10.87	7.01	21.2	5538
					Aug., '95.....	363.8	9.06	5.256	19	4132
					Nov., '95.....	337.4	10	7.16	23.5	5525
					Apr., '96.....	249.5	9.34	5.754	20.2	4545
					Dec., '96.....	24	13.92	4.50	16.6	3353
New Orleans..... Sheathed protected cruiser.	4,001	Vert., triple ex., twin screw.	Scotch.....	800	Apr., '98.....	121.8	11.11	7.607	22.8	6085
					May, '98.....	66.3	12.37	6.883	18.5	5506
					Aug., '99.....	92.3	13.11	4.58	10.35	3257
Newport..... Composite gunboat.	1,128	Vert., triple ex., single screw.	Scotch.....	232	Dec., '97.....	120	8.60	14.5	16.3	3364
					Dec., '97.....	96	9.72	18	18.1	4176
					Mar., '98.....	120	8.2	12	14.1	2767
					July, '98.....	156	8.1	17.4	19	3722

NOTE.—For explanation of reference letters, see pp. 52, 53.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
7	4	B	M	6	Bituminous, poor	North Atlantic	
9	3	B	S	4¾	Pocahontas, good	Do	
7	3	S	S	½	Dowler's Merthyr, good	Mediterranean	
8	4	F	SM	⅔	Mix. of Nixon's St. Nav., poor, and Merthyr, good	North Atlantic	
3	2	B	S	...	Cambrian Navigation, good	Mediterranean	
3	4	BF	MS	2½	Do	Do	
20	3	S	S	...	Cory's National Merthyr, good	Do	
6	3	SM	SM	⅔	Hood's Merthyr, fair	Do	
5	3	FQ	SM	1	Hood's Merthyr and Great Western Navigation, good	North Atlantic	
7	3	B	S	3	Sun River, good	Do	
5	3	...	G	6	Bituminous, poor	North Pacific	
8	3	S	S	2½	Cardiff, good	Do	
7	2	S	M	8⅔	Do	Do	
9	3	S	M	½	Do	Do	
7	3	B	SM	2	Welsh, good	Do	
4	3	FB	M	2½	Bituminous	North and South Pacific	
11	2	BQ	S	4½	Cardiff, good	Do	
2	3	F	S	5¾	Do	North Pacific	
11	4	BQ	M	4	Do	Do	
8	3	FB	MS	5	Do	Do	
4	4	F	GS	11	Comox, fair	Do	
7	3	BQ	MS	1	Cardiff, good	Do	
8	3	B	G	½	Pocahontas, good	North Atlantic	
5	3	F	SMH	6⅓	Milldale, good	Gulf of Mexico	
8	3	QB	SMH	1⅓	Pocahontas, good	North Atlantic	
9	4	QB	GM	2	Do	Do	
5	3	S	S	1⅓	Bituminous	Do	
4	3	F	M	3	New River, fair	Do	
7	3	S	S	7	Milldale	G. of Mexico and N. Atlantic	
11	3	Q	MS	1⅔	Bituminous	North Atlantic	
8	3	F	GM	5	Pocahontas, good	North Atlantic	
10	3	S	S	1	Lehigh and Pocahontas, good	Gulf of Mexico	
6	3	S	S	1½	Pocahontas, good	Do	
7	4–5	B	MS	1½	Do	North Atlantic	
...	...	...	...	5½	Milldale	Do	
...	...	...	...	...	Georges Creek		
...	...	...	MR	5⅔	Australian, fair	North Pacific	Coal used from cargo.
...	...	...	...	2	Comox		
7	4	B	SM	10	Card., Albion, Merthyr and Pow. Duff., good to fair	South Atlantic	Bottom foul.
9	4	S	S	1	Cory's Ocean Merthyr, good	Do	
10	3	S	S	1⅓	Hill's Plym'th, f.; Cory's Mer., g.	Do	
6	4	FB	MR	11	Pow. Duff. and Albion Mer., g.	Do	Bottom foul, sail set 80 p. c. time.
10	3	B	SM	1	Ocean Merthyr, good	Do	Sail set 30 per cent. time.
8	3	S	S	6½	Do	Do	Sail set 40 per cent. time.
10	2	S	S	⅔	Pocahontas, good	Do	
V	3–4	Q	MH	...	Ferndale, good	North Atlantic	
7	3	...	MS	...	Pocahontas and Clearfield, good	Do	
...	...	...	...	8	Cumberland, medium	Do	
6	3	Q	SG	⅔	Bituminous, good	Do	Sail set 50 per cent. time.
8	3	BQ	SM	1	Do	Gulf of Mexico	
...	...	...	...	4	Bituminous	North Atlantic	
...	...	...	...	7	Do	Do	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 42.5 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
New York..... Armored cruiser.	9,021	Vert., triple ex., twin screw, 2 engines for each screw.	Scotch.....	1200	May, '95.....	212.4	13.34	3.74	13.5	4486
					July, '95.....	220.8	13.96	3.5	12.5	4194
					June, '97.....	35	14	3.13	11.2	3756
					Aug., '98.....	96	9.32	4.19	22.4	5028
					Mar., '99.....	122	9.2	4.01	21.7	4812
					Dec., '99.....	140	9.8	4.28	21	5136
					Feb., '00.....	116	9.04	3.27	18.38	4019
					Apr., '00.....	192	8.27	3.3	19.95	3960
					May, '00.....	122	10.44	3.84	18.38	4606
Olympia..... ..... Protected cruiser.	6,602	Vert,, triple ex., twin screw.	Scotch.....	1100	June, '95.....	4	19.5	2.49	5.8	2737
					Aug., '95	85	11.16	4	16.4	4400
					Nov., '95.....	364.3	8.90	3.265	16.8	3592
					Apr., '97	71	14.47	2.79	8.8	3069
					Feb., '98.....	121 4	12.39	4.78	17 6	5253
					Sep., '99.....	375	9.66	3.71	17.6	4070
Oregon..... ..... Battleship.	11,719	Vert., triple ex., twin screw.	Scotch.....	1590	Jan., '97.....	119.1	10.52	3.38	21.3	5382
					Feb., '97.....	121.4	9.20	2.98	21.5	4740
					Apr., '98	375	10.97	4.267	25.7	6784
					Apr., '98.....	213.6	11.94	3.288	17.9	5328
					Apr., '98.....	221	10.16	3.457	22.6	5512
					May, '98.....	193	11.54	3.594	20.6	5714
					May, '98.....	141.5	11.77	3.482	19.5	5536
					Oct., '98.....	450	9.1	3.7	26.9	5883
					Jan , '99.....	431	9.6	3.88	26.8	6170
					Mar., '99	396.5	8.28	3.26	26 1	5180
Peoria..... Converted gunboat	488	Vertical, comp., single screw.	Scotch.....	70	Nov., '98.....	143	10.55	3.48	9.6	2436
Petrel ..... Gunboat.	951	Horiz., comp., single screw.	Cyl., straightway, fire-tube.	200	Apr., '96.....	391.7	8.8	16.56	15.67	3312
					May, '96.....	212.8	9.8	12.48	10.6	2496
					Apr., '97.....	204	9.6	19.46	16.9	3892
					May, '97.....	332.8	10.27	20	16 2	4000
					Oct., '98.....	133	8.08	11.71	12.08	2342
Philadelphia ..... Protected cruiser.	5,305	Hor., triple ex., twin screw.	Scotch.....	1020	July, '93.....	430	11.11	6.23	23.8	6354
					July, '93.....	190.4	10.03	6.23	26.2	6354
					Sep , '93.....	433	12	6.97	24.6	7109
					Aug., '94.....	214	8.91	4.19	20	4273
					Dec., '96.....	356.5	11.44	6.73	25	6804
					Jan., '97.....	142.7	12.64	6.17	20.7	6293
					Apr., '98.....	198	11.91	5.05	18 0	5151
					Oct., '98.....	190	10.19	3.54	14.70	3610
					Nov., '98.....	141	12.33	6.29	21 7	6415
Prairie ..... Auxiliary cruiser.	6,879	Vert., triple ex., single screw.	Scotch.....	1000	May, '98.....	105	12.1	6.30	21.7	6300
					June, '98.....	106	10.6	6.92	27.2	6920
					June, '98.....	83	14	4.74	14.1	4740
					Aug., '98.....	108	13.3	4.56	14.2	4560
Princeton..... Composite gunboat	1,128	Vert., triple ex., single screw.	Scotch.....	239	Jan., '99.....	342	9.4	19.61	20.78	4690
					Aug., '99.....	108	9.4	15.45	16.37	3690
Puritan ..... Monitor.	6,060n	Horiz., comp., twin screw.	Scotch.....	310	Aug., '97.....	34	7.8	2.86	4.7	887
					Sep., '97.....	72	7	3.68	6.6	1140
					Sep., '98.....	96	7.68	3.66	6.1	1134
Raleigh ..... Protected cruiser.	3,462	Vert., triple ex., twin screw.	Scotch.....	539	Mar., '95.....	105.4	10.6	5.52	11.7	2975
					June, '95.....	124 6	10.21	5.095	11.2	2746
					Mar., '96.....	5	18.2	2.91	3.5	1570
					Oct., '96.....	19.3	15.52	4.1	5.9	2210

NOTE.—For explanation of reference letters, see pp. 52, 53.

Coal endurance.		Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
In days.	In knots.	Direction.	Force.	Direction.	Force.				
10	11	12	13	14	15	16	17	18	19
3.5	4486	20	4	B	M	½	Clearfield, good	New York to Southampton	
2.5	4194	4	4	F	SM	2	Nixon's St. Nav., good	Gravesend to New York	
1.2	3756	6	3	B	S	6	New River, poor.	North Atlantic	
2.4	5028	9	3	B	M	10	Bituminous, fair	Guantanamo to New York	
1.7	4812	—	...	...	...	4½	....Do	North Atlantic	
1	5136	...	...	...	...	7			
8.38	4019	V	5	V	MR	9	Pocahontas	Caribbean Sea	
9.95	3900	V	3	V	S	10	Alabama, Eureka and Pocahontas	North Atlantic	
8.38	4606	V	3	V	S	11	Welsh	....Do	
5.8	2737	12	3	S	S	4½	Cardiff, good	North Pacific	
6.4	4400	8	2	S	S	6½	Cardiff, fair	....Do	
6.8	3592	5	3	Q	MR	8½	Wellington, good to fair	....Do	
8.8	3069	6	3	FQ	M	0	Ferndale, good	China Sea	
7.6	5258	8	2	QB	G	2	....Do	....Do	
7.6	4070	...	...	...	...	4	Ferndale		Using port screw and dragging starboard screw.
1.3	5382	8	3	S	S	9	Cardiff, good	North Pacific	
1.5	4740	8	5	V	MRG	9½	....Do	....Do	
5.7	6784	6	3	V	SM	1	Comox, good	North and South Pacific	
7.9	5228	3	3	V	SM	1⅔	Cardiff, good	South Pacific	
2.6	5512	5	3	V	SM	2	....Do	South Atlantic	
0.6	5714	9	3	S	S	2⅔	English, fair	South and North Atlantic	
9.5	5536	9	3	S	S	3	English and Welsh, fair	North Atlantic	
6.9	5883	Generally favorable				1	Pocahontas, good	New York to Bahia	
6.8	6170	13	3	S	SM	5	....Do	Pacific	
6.1	5180	18	4–5	...	MS	5½	⅔ Pocahontas, ⅓ Cumberland	Honolulu to Guam	
9.6	2436	Favorable				...		New York to San Juan	
5.67	3312	6	3	B	M	½	Cardiff, good	Pacific	Sail set 75 per cent. time.
10.6	2496	3	3	S	S	1⅓	Wellington	....Do	Sail set 10 per cent. time.
6.9	3892	7	3	...	M	¾	Cardiff, fair	....Do	Sail set 32 per cent. time.
6 2	4000	9	3	G	S	1⅔	Pocahontas, fair	....Do	Sail set 73 per cent. time.
2.08	2342	6	3	M	M	1			Sail set 25 per cent. time.
3.8	6354	5	3	BG	SG	⅓	Semi-bituminous, good	North and South Atlantic	
6.2	6354	8	4	BF	MG	1¼	Welsh, good	South Atlantic	
4.6	7109	10	5	BQ	GS	2½	Cardiff, good	Pacific	
0	4273	8	3	FQ	MS	14	Wellington, good	North Pacific	
5	6804	8	2	S	S	⅓	Cardiff, good	Pacific	
10.7	6293	0	3	S	S	2	....Do	....Do	
8 0	5151	0	2	S	S	4⅓	Australian, fair	....Do	
4.70	3610	V	3	V	G	10½	Pocahontas & Anthr. slack, poor.	North Pacific	
11 7	6415	11	3	Q	SM	⅓	Comox, fair	....Do	
1.7	6300	0	3	F	S	...	New River and Georges Creek	North Atlantic	
7.2	6920	12	3	Q	S	...	....Do	....Do	
4.1	4740	2	3	B	S	...	Pocahontas	....Do	
4.2	4560	12	2	Q	S	...	Georges Creek	....Do	
10.78	4590	—	...	...	...	...			
6.37	3690	—	...	...	...	4	Bituminous	Asiatic	
4.7	887	6	2	S	S	4⅔	Clearfield, fair	North Atlantic	
6.6	1140	6	1	S	S	5⅓	Pocahontas, good	....Do	
6.1	1134	8	3	...	SM	6	....Do	....Do	
11.7	2975	5	4	...	SM	1¾	....Do	Caribbean Sea	
11.2	2745	11	3	S	S	5	....Do	North Atlantic	
3.5	1570	0	3	...	M	⅓	New River, fair	....Do	
5.9	2210	8	4	Q	HM	2⅓	Pocahontas, good	....Do	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 62.5 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Raleigh..... Continued.	3,462	Vert., triple ex., twin screw.	Scotch.....	539	May, '97.....	236.7	9.53	5.37	12.6	2894
					July, '97	145.3	9.66	4.52	10.5	2436
					Jan., '98.....	213.4	9.37	5.20	12.4	2800
					Jan., '99.....	121.5	13.5	5.8	8.4	2740
					Feb., '99	102	12.49	4.66	8.35	2513
					Apr., '99.....	108.2	9.7	4.28	9.8	2300
San Francisco..... Protected cruiser.	4,627	Hor., triple ex., twin screw.	Scotch.....	627	Jan., '95	142	10.07	6.38	16.5	4000
					Feb., '95.....	118.6	10.68	7.53	18.4	4721
					June, '98.....	72	12.71	4.08	8.4	2558
St. Paul..... Atlantic liner.	16,000	Vert., quad. ex., twin screw.	Scotch.....	2464	May, '98.....	48	19.76	1.39	7.2	3425
					June, '98.....	48	16.64	2.22	13.6	5470
					June, '98.....	72	14.28	2.41	17.3	5938
					July, '98.....	48	19.45	2.14	11.3	5373
					Aug., '98.....	72	19.16	1.916	10.2	4721
Saturn..... Collier.	6,220	Vert., triple ex., single screw.	Scotch.....	335	July, '98.....	24	7.9	12.64	22.3	4234
					July, '98.....	72	9.47	9.09	13.4	3045
Scindia..... Collier.	7,500	Vert., triple ex., single screw.	Scotch.....	450	Nov., '98.....	323	9.28	7.6	15.4	3420
					Dec., '98.....	302	8.83	7.13	15.1	3208
Scorpion..... Converted yacht.	850	Vert., triple ex., single screw.	Yarrow.....	180	May, '98.....	36	11.8	21.5	13.7	3870
					June, '98.....	56	9.5	26.5	21	4770
					Nov., '99.....	116	10.99	17.35	11.84	3213
Solace..... Hospital ship.	4,700	Vert., triple ex., single screw.	Scotch.....	825	June, '98.....	111	12.5	5.1	14.2	4207
					Aug., '98.....	111	12.9	4.7	12.6	3877
					Oct., '98.....	106.5	13.7	5	12.5	4125
					Nov , '98.....	102	9.15	4.6	17.3	3795
					May, '99.....	281.2	11.76	6.92	20.2	5706
Sterling..... Collier.	5,663	Vert., triple ex., single screw.	Scotch.....	578	May, '98.....	145	7.35	11.74	39	6785
					May, '98.....	67	8.4	12.02	34.4	6947
					June, '98	76	9.35	11.73	30.2	6779
Talbot..... Torpedo boat.	58	Vert., triple ex., single screw.	Normand.....	8	June, '98.....	13.7	13.76	40.6	0.95	325
					June, '98.....	9 3	14.62	27.3	¾	318
					July, '98.....	30	10	93	3.1	744
					July, '98.....	45	12	77	2.1	616
					Aug., '98.....	56	8.12	111.7	4.6	893
					Aug., '98.....	19	9.3	86.5	3.1	692
Terror..... Monitor.	3,990*n*	Inclined comp., twin screw.	Scotch.....	260	Apr., '97.....	24	5.88	4.20	7.7	1092
					July, '98.....	48	7.73	5.57	7.4	1448
					July, '98.....	71.5	6.50	4.62	7.7	1201
					Sep., '98.....	96.6	7	4.85	7.5	1261
Texas..... Battleship.	6,770	Vert., triple ex., twin screw.	Scotch.....	830	Feb., '97.....	144.4	12.39	3.43	9.5	2847
					Mar., '97.....	71.2	9.375	3.81	14	3162
					Jan., '98.....	71	9.37	3.65	13.4	3039
					May, '98.....	94	10.66	3.45	11.1	2860
					Feb., '99.....	67	11.29	4.02	12.31	3339
					May, '99.....	135	9.9	3.37	11.71	2797
Topeka..... Iron gunboat.	1,814	Hor., comp., twin screw.	Scotch.....	410	July, '98.....	72	12.4	11.66	16	4780
					Nov., '98.....	72	11.10	8.48	13	3476
Vesuvius..... Dynamite gunboat	929*n*	Vert., triple ex., twin screw.	Marine locomotive.....	145	Feb., '97.....	24	11.6	10.7	5.6	1551
					Mar., '97.....	24	10.33	16.1	9 4	2334
					Apr., '97.....	22	13.34	13.6	6.1	1972
					July, '97.....	96	8.19	8.19	5.8	1187

NOTE.—For explanation of reference letters, see pp. 52, 53.

Wind.		Sea.		Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
Direction.	Force.	Direction.	Force.				
12	13	14	15	16	17	18	19
9	4	Q	SM	2	Clearfield, fair	North Atlantic	
8	2	S	S	5	Cory's Merthyr, good	Mediterranean	
4	3	F	HM	3	Dowlai's Merthyr, good	Arabian Sea	
8–12	1–3	B	MS	1	Mixed Merthyr and Ferndale	Bombay to Aden	
8–12	2–6	BQ	SGMR	1½	Ferndale	Aden to Suez	
8	3–5	Q	M	3	Do	Bermuda to New York	
10	4	BQ	M	1	Semi-bituminous, fair	North Atlantic	Fore and aft sail set 50 p.c. time.
5	3	S	S	2⅓	Cory's Merthyr, good	Mediterranean	
3	3	F	S	2	New River, fair	North Atlantic	
V	4	...	...	?	Bituminous	Do	
V	3–4	...	...	...	Do	Do	
V	3	...	...	...	Do	Do	
V	4	...	...	...	Do	Do	
V	3	S	S	...	Do	Do	
2	3	F	S	3½	Pocahontas, good	Waters of Cuba	
4	3	F	S	3½	Do	Do	
Generally fair.				...	Bituminous	South Atlantic	
Generally fair.				...	Do	South Pacific	
8	2	S	S	1	Bituminous, good	North Atlantic	
3	2	...	M	3	Do	Do	
...	...	...	...	1½	Pocahontas	Waters of Cuba	
...	...	...	...	2	Bituminous, good	Do	
...	...	...	...	5	Pocahontas, good	Guantanamo to Boston	
...	...	...	...	6	Do	San Juan to Sandy Hook	
...	...	...	...	1	Do	Gibara, Cuba, to S. Hook	
...	...	...	...	4	Cardiff, good		
B	...	S	S	...	Pocahontas, fair	North Atlantic	
F	...	S	S	...	Do	Do	
B	...	...	...	...	Do	Do	
2	2	S	S	0	Pocahontas, good	Brooklyn to Delaware City	
0	3	S	S	0	Pocahontas, fair	Delaware City to Norfolk	
2	4	2	M	0	Pocahontas, good	North Atlantic	
16	2	12	M	0	Georges Creek, fair	Do	
8	4	8	M	1⅓	Pocahontas, good	Do	
0	0	S	S	1⅓	Do	Do	
5	2	F	S	2½	Do	Do	
3	3	F	S	6⅓	Do	Cuban waters	
2	3	F	M	6⅓	Do	Do	
8	3	FQ	MS	8	Do	Do	
7	3	S	S	2	Bituminous, good	N. Atlantic and G. of Mex	
6	3	S	S	3⅓	Do	Do	
5	4	S	S	1	Bituminous, fair	North Atlantic	
4	3	S	S	4⅔	Do	Do	
...	...	...	...	...		Do	
...	...	...	...	...			
3	3	S	S	2	Bituminous	Cuban waters	
4	3	F	RM	6	Do	North Atlantic	
12	3	S	S	7	Anthracite, good	Do	
8	5	...	M	8	Pocahontas, good	Do	
V	2	S	S	8	Bituminous and Anthracite	Do	
9	2	S	S	12	Georges Creek, fair	Waters of Florida	

Name and type of vessel.	Full load displacement. Tons.	Type of engines.	Type of boilers.	Bunker capacity. Tons of 42.5 cu. ft.	Date of trip.	Number of hours.	Speed in knots.	Knots run per ton of coal.	Coal endurance. In days.	Coal endurance. In knots.
1	2	3	4	5	6	7	8	9	10	11
Vesuvius Continued.	929π	Vert., triple ex., twin screw.	Marine locomotive	145	Oct., '97	48	11.23	13.36	7.1	1937
					Mar., '98	50	12.76	10.9	5.2	1580
					May, '98	38	11.32	12.6	6.7	1827
Vicksburg Composite gunboat	1,128	Vert., triple ex., single screw.	Scotch	235	Jan., '98	24	9.38	20.96	21.8	4925
					Mar., '98	24	9.6	21.87	22.3	5140
					Jan., '98	47.4	9.59	21.5	22	5052
					Mar., '98	72	10.32	23.6	22.4	5546
					Aug., '98	95.6	8.89	15.64	17.2	3675
Vixen Converted yacht.	806	Vert., triple ex., single screw.	Scotch	170	Oct , '99	191	7.2	14.05	13.82	2389
Wheeling Composite gunboat	1,170	Vert., triple ex., twin screw.	Scotch	226	Oct., '97	192.8	9.83	17.9	17	4045
					Nov., '97	214	9.2	16.6	17	3731
					June, '98	81.5	10.21	15.91	14.6	3595
					Oct., '98	72	9.87	17	16.1	3842
					Mar., '99	293	8.1	15.7	18.2	3543
					Apr., '99	132	9.9	23.3	22.16	5324
Wilmington Gunboat.	1,689	Vert., triple ex., twin screw.	Scotch	280	June, '97	65	8.26	9.92	14	2776
					June, '97	48	7.71	8.04	12.1	2251
					Sep , '97	50	8.4	7.69	10.6	2152
					Mar., '98	72	8.56	8.04	10.9	2251
					Mar., '99	94	8.9	9.1	12	2548
Yorktown Gunboat.	1,921	Hor., triple ex., Twin screw.	Cyl., straightway, fire-tube.	400	May, '97	70.7	10.92	6.83	10.4	2732
					Sep., '97	48	11.12	10	15	4000
					Oct., '97	307.6	10.04	9.06	15	3624
					Nov., '97	189.5	10.42	8.62	13.7	3448
					Jan., '99	404.8	8.09	10.6	21.8	4333
Yosemite Auxiliary cruiser.	6,179	Vert., triple ex., single screw.	Scotch	1,290	May, '99	72	13.7	5.36	21.06	6918
					June, '99	276	11.5	5.64	26 4	7280

NOTE.—For explanation of reference letters, see pp. 52, 53.

Coal endurance. In days.	Coal endurance. In knots.	Wind. Direction.	Wind. Force.	Sea. Direction.	Sea. Force.	Months out dock.	Kind and quality of coal.	Cruising ground.	Remarks.
10	11	12	13	14	15	16	17	18	19
.1	3337	10	3	...	SM	2	New River and Anthracite, fair...	North Atlantic.....	
.2	1586	V	2	B	M	7	Georges Creek, good.....	.....Do.....	
.7	1827	...	1-2	S	S	1	Pocahontas, good.....	.....Do.....	
.8	4935	8	3	...	SM	2½	Cumberland, good.....	.....Do.....	
.3	5140	6	3-4	S	S	4⅔	Glenwood, good.....	.....Do.....	
	5052	10	3	Q	MG	2	..... Do.....	.....Do.....	
.4	5546	7	3	S	S	5	Cory's Mer. and Glenwood, good..	West Indies.....	
.2	3675	6	3	...	MS	10	Bituminous, fair.....	Waters of Cuba.....	
.82	2389	5	...	...	...	5	Cardiff coal and patent fuel, poor..	.....	
	4045	9	3	BQ	SM	4	Westport, good.....	North Pacific.....	Fore and aft sail 26 p.c. time.
	3751	3	4	FB	RMS	6	Nanaimo, poor.....	.....Do.....	Fore and aft sail 34 p.c. time.
.6	3595	5	3	FB	MS	2	Comox, fair.....	.....Do.....	Fore and aft sail 26 p.c. time.
.1	3842	8	3	BQ	MS	6	Comox, good.....	.....Do.....	
.2	3543	...	...	..	...	...	Wellington and Nanaimo.....	.....	
.16	5264	...	...	...	...	...	Pocahontas and Wellington.....	Guam to Manila.....	
	2776	5	3	S	S	2	Pocahontas, good.....	North Atlantic.....	
.1	2251	3	5	S	S	3	.....Do.....	.....Do.....	
.6	2152	3	2	S	S	5½	Clearfield.....	.....Do.....	
.9	2251	11	3	S	S	⅓	Pocahontas, good.....	West Indies.....	
	2548	...	...	...	...	6	Bituminous.....	South Atlantic.....	
.4	2732	5	1	S	S	⅓	Bituminous, poor.....	North Pacific.....	
	4000	5	3	S	S	0	Bituminous, good.....	.....Do.....	
	3624	4	3	B	MS	1	Ferndale, good...	.....Do.....	
.7	3448	5	3	F	MS	2	Departure Bay, poor.....	.....Do.....	
.8	4333	...	...	...	...	...	Cumberland.	Honolulu to Guam.....	
.06	6928	...	...	...	...	5⅓	Pocahontas.....	.....	
.4	7280	...	...	...	...	6	Cardiff.....	Port Said to Singapore.....	

TESTS OF THE BOILER OF THE PURDUE LOCOMOTIVE.

By W. F. M. Goss.

[Abstract of a paper read before the American Society of Mechanical Engineers, at the New York meeting, December, 1900.]

I.—THE LOCOMOTIVE AND ITS BOILER.

The boiler tests herein described represent a portion of the results obtained during a period of two years in the course of the regular work of the Purdue locomotive testing laboratory. The principles underlying the action of the testing plant are now generally understood, and need not be completely described. It should be said, however, that such a plant provides for the complete operation of a locomotive while permitting it to occupy a fixed position in the laboratory. The locomotive on the plant is fired as upon the road, delivers its power from the periphery of its drivers as it would do if passing along a track, and, while thus operated, is tested with the same facility as a stationary plant. The original locomotive testing plant of Purdue University was described in the Proceedings of the Association (American Society of Mechanical Engineers) for 1892, Vol. XIII. In 1894 this plant suffered damage by fire, and was re-established in a form much more complete than that which it had previously possessed. The new plant went into operation in the latter part of 1894, and is described in a publication issued by the University.

The locomotive upon which the tests were made is that now known as Schnectady, No. 1.* It is of the 8-wheel type. Its characteristics are, briefly described, as follows:

* In May, 1897, this engine was replaced by one of more recent design. It has since been in service on the Michigan Central Railroad, where it is known as No. 422.

Total weight, pounds	85,000
Weight on drivers, pounds	56,000
Total wheel base, feet and inches	22–11
Driving-wheel base, feet and inches	6– 6
Diameter of pistons, inches	17
Stroke of pistons, inches	24
Diameter of piston rods, inches	3
Diameter of drivers, inches	63

The form and principal dimensions of the boiler are shown in Fig. 1. It is of the ordinary crown-bar type, having a narrow fire box and no brick arch. It was designed to carry a pressure of 140 pounds, at which limit its safety valves were usually set. The boiler was at all times perfectly tight, and was kept clean. Its characteristics are as follows:

Diameter waist at front end, inches	52
tubes, outside, inches	2
inside, inches	1.78
Number of tubes	200
Length of tubes, feet	11.5
Thickness of tubes, inch	.11
Area of flameway through tubes, square feet	3.46
Width of fire box, inches	34.5
Length of fire box, inches	72
Height of fire box, inches	73
Heating surface in fire box, square feet	132.1
front head, square feet	10.5
tubes calculated from outside diameter, square feet	1,204.3
inside diameter, square feet	1,071.8
Total heating surface, assuming the tube surface to be calculated from outside, diameter, square feet	1,346.9
Total heating surface, assuming the tube surface to be calculated from the inside, diameter, square feet	1,214.4
Grate area, square feet	17.25
Ratio of heating surface to grate area:	
Assuming heating surface to be 1,346.9 square feet	78.1
1,214.4 square feet	70.4
Pounds of water in boiler when filled to middle gage	8,450
Steam space in boiler when filled to middle gage, cubic feet	52.8
Ratio of steam space to entire cubical capacity of boiler	.29

II.—THE TESTS.

The results herewith presented are from the first thirty-five tests which were run immediately following the re-establishment

of the testing plant after its damage by fire in February, 1894. The tests were run by senior students in mechanical engineering as a part of the regular routine of the laboratory, and involved observations as to engine performance as well as those concerning the performance of the boiler. The present paper deals only with the performance of the boiler. While many have aided in the advancement of the work, it is fitting that specific mention be made of the assistance rendered by Prof. Robert S. Miller, junior member of the Society, who, when an assistant in the laboratory, checked all calculated results, and afterwards led in the development of many of the comparisons which are presented.

The final results only are given. These are generally the average of values obtained from observations made at five-minute intervals. In most cases the individual observations were checked by two different observers using separate instruments, or they have been taken by one observer and checked by some form of automatic recording instrument. All derived results have been calculated by two or more independent workers.

A hasty review of the data will disclose some inconsistencies. The number of these could have been greatly reduced, and the general appearance of record improved by the omission of a few tests. From an experimental point of view, however, all are believed to be equally reliable, and there seems to be no more reason for omitting a test, the results of which fall out of line, than for omitting another, the results of which are in line. For this reason the exhibit is a complete presentation, so far as the boiler is concerned, of all the work undertaken during the whole period covered by the tests.

General Conditions (Table I).—Individual tests may be identified by number, by laboratory designation, or by date. As each of these separate forms of notation express certain relationships, all are given in each table. The tests are arranged in order on the basis of the rate of evaporation, the consecutive number (column 1) indicating at once the relative position of each test with reference to the factor named. Test 1 is that test for which the rate of evaporation is least, and test 35 that test for which it is greatest.

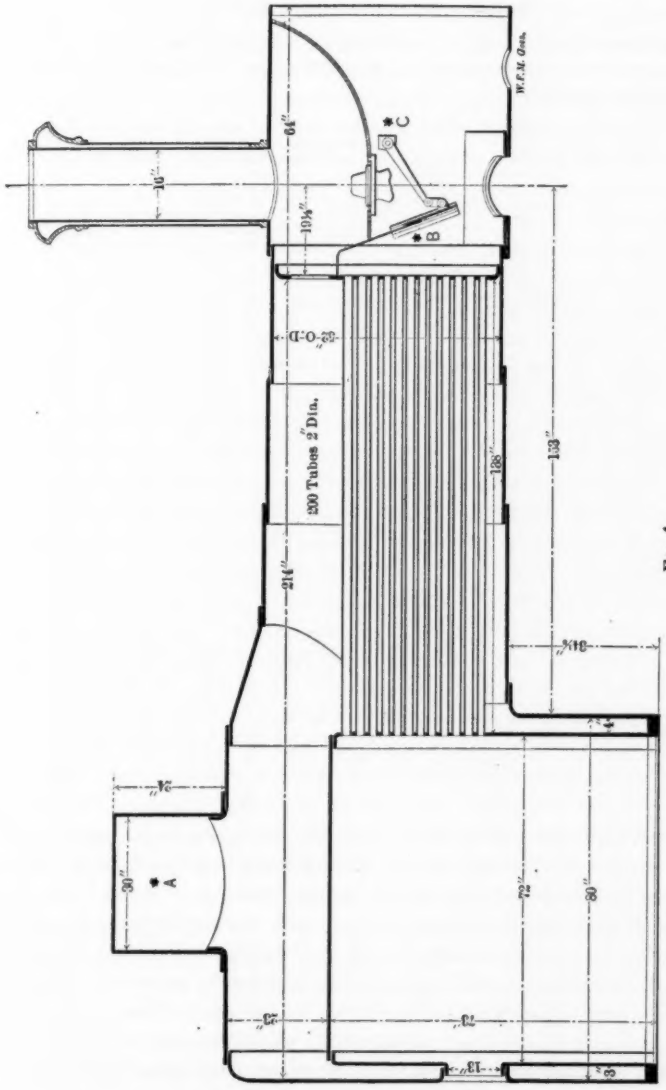


FIG. 1.

THE BOILER OF THE EXPERIMENTAL LOCOMOTIVE.

The calorimeter received its supply from the point A, the temperature of the smoke box was taken at B, and the draught from the point C,

TABLE I.—GENERAL CONDITIONS.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.			Duration of test in minutes.	Average pressure, pounds per square inch.			Average temp., deg., Fahr.	
Consecutive number.	Laboratory designation.	Date of test.		Steam pressure in boiler by gage.	Atmospheric pressure.	Absolute steam pressure.	Of laboratory.	Of feed water.
1	2	3	4	5	6	7	8	9
1.....	15—1—*A*	Dec. 12, 1894	240	125.9	14.5	140.4	65	53.2
2.....	15—1[b]—*V*	Nov. 23, 1894	190	127.3	14.5	141.8	74	53.8
3.....	15—1—*H*	Dec. 9, 1896	180	123.6	14.3	137.9	72	54.6
4.....	25—1—*A*	Dec. 14, 1894	255	120.1	14.5	134.6	67	53.8
5.....	15—1—*G*	Nov. 9, 1896	180	123.6	14.4	138.0	69	53.3
6.....	15—2—*A*	Nov. 13, 1895	180	129.5	14.4	143.9	79	55.2
7.....	25—1—*V*	Nov. 26, 1894	240	127.1	14.3	141.4	70	53.9
8.....	35—1—*A*	Dec. 17, 1894	180	129.7	14.6	144.3	75	53.2
9.....	35—2—*F*	Jan. 21, 1895	180	155.4	14.7	170.1	71	52.7
10.....	35—1—*V*	Dec. 7, 1894	140	128.9	14.3	143.2	69	51.9
11.....	35—2—*E*	Jan. 16, 1895	180	128.1	14.5	142.6	71	51.9
12.....	45—1—*A*	Nov. 20, 1895	150	128.8	14.3	143.1	76	56.4
13.....	35—2—*B*	Jan. 14, 1895	170	98.4	14.4	112.8	66	50
14.....	55—1—*A*	Nov. 25, 1895	120	124.9	12.2	139.1	76	56
15.....	35—1—*H*	Dec. 18, 1896	160	121.2	14.6	135.8	67	52.6
16.....	35—1—*G*	Nov. 20, 1896	170	125.0	14.6	139.6	74	55
17.....	35—1[b]—*G*	Dec. 2, 1896	170	128.2	14.6	142.8	78	52.5
18.....	25—2—*A*	Oct. 25, 1895	180	129.3	14.4	143.7	85	56
19.....	55—1—*V*	Dec. 18, 1895	120	128.4	14.4	142 8	76	58.1
20.....	35—2[b]—*H*	Feb. 10, 1897	160	122.6	14 5	137.1	74	50.6
21.....	55—1—*H*	Feb. 11, 1897	120	127.5	14.4	141.9	71	52.1
22.....	55—1—*G*	Nov. 23, 1896	120	126.9	14.5	141.4	79	54.2
23.....	15—9—*A*	Nov. 6, 1896	150	122.5	14.3	136.8	79	55.6
24.....	15—9—*H*	Dec. 11, 1896	180	122.7	14.4	137.1	81	53 2
25.....	35—2—*A*	Dec. 19, 1894	180	123.0	14.5	135.7	72	52.5
26.....	35—3—*G*	Dec. 4, 1896	140	125.9	14.3	140.2	70	52.6
27.....	15—9—*G*	Nov. 12, 1896	160	124.1	14.5	138.6	77	53.1
28.....	35—3—*H*	Dec. 14, 1896	120	116.5	14.3	130.8	73	53
29.....	35—2—*G*	Nov. 13, 1896	160	121.0	14.5	135.5	78	53 6
30.....	35—2—*H*	Dec. 16, 1896	120	112.0	14.6	126.6	72	53
31.....	45—2—*A*	Nov. 18, 1895	140	126.7	14.3	141.0	84	55
32.....	25—3—*A*	Nov. 1, 1895	122.5	127.2	14.5	141.7	76	53.3
33.....	35—2—*G*	Jan. 23, 1895	120	143.3	14.4	157.7	71	51.7
34.....	55—2—*A*	Nov. 22, 1895	68	124.0	14 4	138.4	76	58.4
35.....	35—3—*A*	Nov. 15, 1895	120	125.3	14.3	139.6	77	55.5

The laboratory designation (column 2) expresses the speed of the engine, the position of the reverse lever (notches forward of center), and the series to which the test belongs. Thus, 15—1—*A* signifies that the test was made with the engine running at a rate of 15 miles an hour, with the reverse lever in the first notch forward of center, and the test belongs to series *A*. The series letter usually refers to engine conditions. For example, series *A* and *V* represent, respectively, two series run in parallel, with a constant boiler pressure, with the throttle wide open, and

at varying speeds and cut-off. For the *V* series the valves were so set that the lead was considerable, while for the *A* series the lead was reduced. As these engine conditions do not in any way affect the boiler performance, the significance of the series letters need not be further defined. The dates upon which the several tests were run (column 3) discloses their actual sequence. The first (No. 2) was run in November, 1894, and the last (No. 21) in February, 1897.

To those accustomed to reviewing data derived from stationary boilers, the duration of the tests (column 4) will appear insufficient, but it is, in fact, satisfactory. The arguments sustaining the practice involving short tests for locomotives on a testing plant have been presented to the Society's committee having in charge the revision of the code relative to a standard method of conducting boiler tests, and will be found presented in the published correspondence of that committee (Volume XXI, page 112). The tests herein recorded were run several years in advance of the presentation of the committee's final report, and for this reason it will be of interest to call attention to the fact that fifteen out of the thirty-five tests perfectly fulfill the requirements of the present code. In defense of those which are shorter than allowed by the code, it should be said that the writer recommended that the limit applying in such cases be the burning of a total for the test of not less than 100 pounds of coal per foot of grate surface. The committee adopted the general form of the recommendation, but fixed the limit at 250 pounds. For two of the tests presented the total fuel per foot of grate per hour is slightly below 150 pounds, and for four others it is below 200.

The boiler pressure (column 5) was practically the same for all tests, save two, and for these it was intentionally higher than the normal in the one case and lower in the other. Pressures were observed from an ordinary dial gage at five-minute intervals, and also recorded by a Bristol gage. To better show the fluctuations in pressure, the chart of this and other recording gages used about the locomotive have a rapid motion, making a complete revolution in six hours.

The atmospheric pressure, the absolute steam pressure, the

temperature of the laboratory and of the feed-water (columns 6 to 9) require no explanation.

Actual Evaporation (Table II).—This table shows (columns 10 and 11) the regularity with which water was delivered to the boiler, the total pounds delivered to the injector during the test (column 12), the pounds caught from injector overflow (column 13), the pounds received by the boiler (column 14), and the rate at which the evaporation proceeded (column 15). In all tests

TABLE II.—ACTUAL EVAPORATION.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.			Duration of test in minutes.	Water and steam.					
Consecutive numbers.	Laboratory designation.	Date of test.		Number of times injector started.	Minutes one or both injectors were in action.	Total pounds of water delivered to injectors.	Pounds of water lost from injector overflow.	Pounds of water delivered to boiler and presumably evaporated.	Pounds of water evaporated per hour.
1	2	3	4	10	11	12	13	14	15
1...	15—1—*A*	Dec. 12, 1894	240	22	130	22,415	315	22,100	5,525
2...	15—1b—*V*	Nov. 23, 1894	190	14	129	17,925	135	17,790	5,618
3...	15—1—*H*	Dec. 9, 1896	180	7	126	18,349	126	18,223	6,075
4...	25—1—*A*	Dec. 14, 1894	255	10	236	25,995	100	25,895	6,093
5...	15—1—*G*	Nov. 9, 1896	180	12	127	18,768	72	18,696	6,232
6...	15—2—*A*	Nov. 13, 1895	180	9	149	21,885	44	21,841	7,280
7...	25—1—*V*	Nov. 26, 1894	240	7	213	29,598	32	29,476	7,369
8...	35—1—*A*	Dec. 17, 1894	180	8	180	24,408	100	24,368	8,123
9...	35—2—*F*	Jan. 21, 1895	180	9	149	24,793	460	24,333	8,111
10...	35—1—*V*	Dec. 7, 1894	140	1	136	19,899	0	19,899	8,528
11...	35—2—*E*	Jan. 16, 1895	180	3	175	25,742	45	25,697	8,560
12...	45—1—*A*	Nov. 20, 1895	150	2	146	21,688	15	21,673	8,669
13...	35—2—*B*	Jan. 14, 1895	170	8	158	24,728	173	24,545	8,666
14...	55—1—*A*	Nov 25, 1895	120	1	120	17,970	87	17,883	8,941
15...	35—1—*H*	Dec. 18, 1896	160	1	160	24,793	70	24,723	9,271
16...	35—1—*G*	Nov. 20, 1896	170	1	170	26,598	35	26,563	9,375
17...	35—1b—*G*	Dec. 2, 1896	170	1	170	26,753	10	26,743	9,439
18...	25—2—*A*	Oct. 25, 1895	180	1	180	28,911	5	28,906	9,635
19...	55—1—*V*	Dec. 18, 1895	120	1	120	19,526	108	19,418	9,709
20...	35—2b—*H*	Feb. 10, 1897	160	1	160	25,834	5	25,829	9,686
21...	55—1—*H*	Feb. 11, 1897	120	1	120	20,514	0	20,514	10,257
22...	55—1—*G*	Nov. 23, 1896	120	1	120	20,791	30	20,761	10,381
23...	15—9—*A*	Nov. 6, 1896	150	1	150	28,582	60	28,522	11,409
24...	15—9—*H*	Dec. 11, 1896	180	1	180	34,403	30	34,373	11,458
25...	35—2—*A*	Dec. 19, 1894	180	1	180	34,354	29	34,325	11,442
26...	35—3—*G*	Dec. 4, 1896	140	1	140	27,060	0	27,060	11,597
27...	15—9—*G*	Nov. 12, 1896	160	1	154	30,877	5	30,872	11,577
28...	35—3—*H*	Dec. 14, 1896	120	1	120	23,446	60	23,386	11,693
29...	35—2—*G*	Nov. 13, 1896	160	1	160	32,886	40	32,846	12,317
30...	35—2—*H*	Dec. 16, 1896	120	3	115	24,793	60	24,733	12,367
31...	45—2—*A*	Nov. 18, 1895	140	1	140	29,313	213	29,100	12,472
32...	25—3—*A*	Nov. 1, 1895	122.5	1	122.5	26,415	14	26,401	12,931
33...	35—2—*G*	Jan. 23, 1895	120	3	120	26,034	25	26,009	13,004
34...	55—2—*A*	Nov. 22, 1895	68	1	68	16,188	277	15,911	14,039
35...	35—3—*A*	Nov. 15, 1895	120	1	120	29,984	109	29,875	14,937

an effort was made to keep the injector constantly in action but for those of low power the rate of delivery could not be made sufficiently small to permit this being done. The data for a few of the tests show the injector to have been started two or more times, while its period of action is recorded as coincident with the length of the test. This apparent inconsistency is explained by the fact that it was sometimes convenient to change from one injector to the other during the progress of the tests, and at other times both injectors were in action at the same time. Column 10 merely shows the number of starts made, and includes the record for both injectors. The last column of this table discloses something of the significance of the conditions attending the action of the locomotive boiler. For example, test 35 shows that nearly 15,000 pounds of water were delivered to the boiler and presumably evaporated each hour, or, approximately, 250 pounds per minute. This rate of very nearly a barrel a minute, is sufficient to evaporate an amount of water equal to the full water capacity of the boiler in 34 minutes. At this rate, had the injectors ceased in their action, the water level would have fallen between the upper and the middle gages at the rate of one inch each minute.

Quality of Steam and Equivalent Evaporation (Table III).—The quality of steam, assuming dry saturated steam to be unity, is shown by column 16, and the percentage of moisture by column 17. Results were obtained by the use of a throttling calorimeter of an improved form, taking steam from a perforated pipe extending horizontally into the dome of the boiler at a height equal to that of the throttle opening. Observations were made at five-minute intervals. An examination of the table will show that, in general, the amount of moisture in the steam increases as the rate of evaporation is increased, though variations in individual results are so great that they do not fall in any well-defined line. The reason for apparent inconsistencies is to be looked for either in the methods employed, or in actual variations in the performance of the boiler. The methods employed were the same for all tests, while the condition of the boiler was necessarily subject to change. The boiler had to be frequently

TABLE III.—QUALITY OF STEAM AND EQUIVALENT EVAPORATION.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest. A complete statement of all data for these and other tests is given elsewhere.

Identification of test.			Duration of tests in minutes.	Results of calormic tests.		Equivalent evaporation from and at 212 degrees Fahrenheit per hour.	
Consecutive number.	Laboratory designation	Date of test.		Quality of steam in dome of boiler, dry saturated steam being taken as unity.	Percentage of moisture in steam.	Assuming quality of steam as shown by column.	Assuming all water delivered to boiler to have been completely evaporated into dry steam.
1	2	3	4	16	17	18	19
1	15—1—*A*	Dec. 12, 1894	240	.9951	0.49	6,659	6,683
2	15—1b—*V*	Nov. 23, 1894	190	.9937	0.63	6,763	6,704
3	15—1—*H*	Dec. 9, 1896	180	.9838	1.62	7,249	7,337
4	25—1—*A*	Dec. 14, 1894	255	.9922	0.78	7,318	7,360
5	15—1—*G*	Nov. 9, 1896	180	.9894	1.06	7,476	7,535
6	15—2—*A*	Nov. 13, 1895	180	.9924	0.76	8,745	8,796
7	25—1—*V*	Nov. 26, 1894	240	.9932	0.68	8,865	8,910
8	35—1—*A*	Dec. 17, 1894	180	.9917	0.83	9,771	9,832
9	35—2—*F*	Jan. 21, 1895	180	.9900	1.00	9,785	9,855
10	35—1—*V*	Dec. 7, 1894	140	.9937	0.63	10,284	10,332
11	35—2—*E*	Jan. 16, 1895	180	.9932	0.68	10,324	10,377
12	45—1—*A*	Nov. 20, 1895	150	.9913	0 87	10,395	10,463
13	35—2—*B*	Jan. 14, 1895	170	.9931	0.69	10,413	10,467
14	55—1—*A*	Nov. 25 1895	120	.9878	1.22	10,691	10,788
15	35—1—*H*	Dec. 18, 1896	160	.9851	1.49	11,090	11,214
16	35—1—*G*	Nov. 20, 1896	170	.9886	1.14	11,226	11,322
17	35—1b—*G*	Dec. 2, 1896	170	.9860	1.40	11,312	11,430
18	25—2—*A*	Oct. 25, 1895	180	.9910	0.90	11,554	11,633
19	55—1—*V*	Dec. 18, 1895	120	.9912	0.88	11,624	11,700
20	35—2b—*H*	Feb. 10, 1897	160	.9880	1.20	11,634	11,737
21	55—1—*H*	Feb. 11, 1897	120	.9871	1.29	12,303	12,422
22	55—1—*G*	Nov. 23, 1896	120	.9869	1.31	12,426	12,548
23	15—9—*A*	Nov. 6, 1896	150	.9906	0.94	13,670	13,766
24	15—9—*H*	Dec. 11, 1896	180	.9871	1.29	13,722	13,853
25	35—2—*A*	Dec. 19, 1894	180	.9894	1.06	13,735	13,843
26	35—3—*G*	Dec. 4, 1896	140	.9838	1.62	13,867	14,035
27	15—9—*G*	Nov. 12, 1896	160	.9871	1.29	13,869	14,002
28	35—3—*H*	Dec. 14, 1896	120	.9873	1.27	13,995	14,128
29	35—2—*G*	Nov. 13, 1896	160	.9856	1.44	14,725	14,884
30	35—2—*H*	Dec 16, 1896	120	.9866	1.34	14.771	14,932
31	45—2—*A*	Nov. 18, 1895	140	.9876	1.24	14,926	15,065
32	25—3—*A*	Nov. 1, 1895	122 5	.9889	1.11	15,515	15,644
33	35—2—*G*	Jan. 23, 1895	120	.9930	0.70	15,709	15,788
34	55—2—*A*	Nov. 22, 1895	68	.9887	1.13	16,773	16,903
35	35—3—*A*	Nov. 15, 1895	120	.9889	1.11	17,883	18,032

washed. It is conceivable that dryer steam may be furnished by the boiler when newly washed than when in a condition requiring washing, though there is nothing in the data either to sustain or to discredit such a conclusion. It has, however, been shown by Professor Jacobus that almost all moisture which may be intermixed with steam passing a horizontal pipe separates

itself from the steam by gravitation, and forms a rill in the bottom of the pipe, the steam above being approximately dry. Experiments by the writer, involving a visual examination of the steam space of a boiler while in action revealed no haze or mist above the surface of the water, thus sustaining the conclusion that the steam within the steam space of the boiler is ordinarily dry and saturated; the water is present as water, and the steam as steam. They are not intermixed. If this is true, the steam which passes the throttle of a locomotive should be expected to be dry, and it would be entirely so if it were not that the violence of the circulation projects small beads of water upward, far beyond the general surface. Some of these enter the throttle with the steam. This action explains why the moisture increases with the power of the boiler, and makes it not unreasonable to assume that the purity of the water in the boiler may actually affect the quality of the steam.

The comparative dryness of the steam under all conditions is a fact worthy of emphasis, for the locomotive is often credited with carrying over a great deal of water to the cylinders. The tests show that this does not happen under constant conditions of running. When it occurs it is probably the result of too high a water level or of a sudden demand upon the boiler. For example, if the throttle of a locomotive, which has been for some time inactive, is quickly opened, large volumes of steam bubbles leave the heating surface and crowd to the upper part of the boiler, making spray in the dome, a portion of which may pass out with the steam. A similar action occurs when an engine which has been working at a light load is suddenly required to increase its power. But these are exceptional conditions. Under uniform conditions of running, such as prevailed throughout the tests herein presented, the moisture passing the throttle is never great.

If, as the writer believes, it is fair to conclude that variations in moisture are largely due to incidental conditions, no serious mistake would be made if the indications of the calorimeter were entirely disregarded, and all calculations based on the assumption that the steam generated is dry and saturated. Results

thus obtained should be somewhat more consistent, one with another, than those corrected for moisture, and hence for general purposes more satisfactory. In accord with this view, while none of the calorimeter work has been ignored in calculating results, many of the derived results have been carried out in duplicate. Thus the equivalent evaporation is first determined

TABLE IV.—POWER.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.			Duration of test in minutes	Equivalent evaportion from and at 212 deg. F., pounds, assuming quality of steam as shown by column 16.			Rated horsepower 34.5 evaporation units, assuming quality of steam as shown by column 16.		
Consecutive numbers.	Laboratory designation.	Date of test.		Water per hour.	Water evaporated per square foot of grate surface per hour.	Water evaporated per square foot of heating surface per hour.	Total.	Per square foot of heating surface.	Per square foot of grate surface.
1	2	3	4	18	20	21	22	23	24
1...	15—1—*A*	Dec. 12, 1894	240	6,659	386	5.48	193	.159	11.2
2...	15—1[b]—*V*	Nov. 23, 1894	190	6,763	392	5.57	196	.161	11.4
3...	15—1—*H*	Dec 9, 1896	180	7,249	420	5.97	210	.173	12.2
4...	25—1—*A*	Dec. 14, 1894	255	7,318	424	6.03	212	.175	12.3
5...	15—1—*G*	Nov. 9, 1896	180	7,476	433	6.16	217	.179	12 6
6...	15—2—*A*	Nov. 13, 1895	180	8,745	507	7.20	253	.208	14.7
7...	25—1—*V*	Nov 26, 1894	240	8,865	514	7.30	257	.212	14.8
8...	35—1—*A*	Dec. 17, 1894	180	9,771	566	8.05	283	.233	16 4
9...	35—2—*F*	Jan. 21, 1895	180	9,785	567	8.06	284	.234	16.4
10...	35—1—*V*	Dec. 7, 1894	140	10 284	596	8.47	298	.245	17.3
11...	35—2—*E*	Jan. 16, 1895	180	10,324	598	8.51	299	.246	17.3
12...	45—1—*A*	Nov. 20, 1895	150	10,395	603	8 56	301	.248	17.4
13...	35—2—*B*	Jan. 14, 1895	170	10,413	604	8 57	302	.249	17.5
14...	55—1—*A*	Nov 28, 1895	120	10,691	619	8.80	310	.255	17.9
15...	35—1—*H*	Dec. 18, 1896	160	11,090	643	9.13	321	.264	18.6
16...	35—1—*G*	Nov. 20, 1896	170	11,226	650	9.24	325	.268	18 8
17...	35—1[b]—*G*	Dec. 2, 1896	170	11,312	655	9.31	328	.270	19.0
18...	25—2—*A*	Oct. 25, 1895	180	11,554	669	9.51	335	.276	19.4
19...	55—1—*V*	Dec. 18, 1895	120	11,624	673	9.57	337	.278	19.5
20...	35—2[b]—*H*	Feb. 10, 1897	160	11,634	674	9.58	337	.278	19.5
21...	55—1—*H*	Feb. 11, 1897	120	12,303	713	10.13	357	.294	20.7
22...	55—1—*G*	Nov. 23, 1896	120	12,426	720	10.23	360	.296	20.9
23...	15—9—*A*	Nov. 6, 1896	150	13,670	792	11.25	396	.326	22.9
24...	15—9—*H*	Dec. 11, 1896	180	13,722	796	11.29	398	.328	23.1
25...	35—2—*A*	Dec. 19, 1894	180	13,735	796	11.31	398	.328	23.1
26...	35—3—*G*	Dec. 4, 1896	140	13,867	804	11.42	402	.331	23.3
27...	15—9—*G*	Nov. 12, 1896	160	13,869	804	11.42	402	.331	23.3
28...	35—3—*H*	Dec. 14, 1896	120	13,995	811	11 52	406	.334	23.5
29...	35—2—*G*	Nov. 13, 1896	160	14,725	853	12.12	427	.352	24 8
30...	35—2—*H*	Dec. 16, 1896	120	14,771	856	12.16	428	.353	24.8
31...	45—2—*A*	Nov. 18, 1895	140	14,926	865	12.29	433	.357	25.1
32...	25—3—*A*	Nov. 1, 1895	122.5	15,515	899	12.77	450	.370	26.1
33...	35—2—*C*	Jan. 23, 1895	120	15,709	911	12.93	455	.375	26.4
34...	55—2—*A*	Nov. 22, 1895	68	16,773	973	13 81	486	.400	28 2
35...	35—3—*A*	Nov. 15, 1895	120	17,883	1,037	14.73	518	.427	30.0

on the assumption that the steam has the quality shown by the calorimeter (column 18), and is also determined on the assumption that all water delivered to the boiler is evaporated into dry and saturated steam (column 19). In accord with the usual practice, however, comparisons which follow are based on the corrected results (column 18).

Power of Boiler (Table IV).—The power developed by the boiler is proportional to the rate of evaporation (column 18). A few comparisons will serve to show something of the peculiar conditions under which the boiler of a locomotive performs its service. Thus the water evaporated per foot of grate surface (column 20) varies from less than 400 to more than 1,000 pounds per hour. These figures reflect well the intensity of the furnace action, which must provide for the combustion of sufficient fuel to produce such a result. Similarly the weight of water evaporated per square foot of heating surface (column 21) varies from $5\frac{1}{2}$ to nearly 15 pounds per hour, the maximum rate being nearly the equivalent of a boiler horsepower for every 2 feet of heating surface in the boiler. The total boiler horsepower (column 22); the horsepower per square foot of heating surface (column 23); and the horsepower per square foot of grate surface (column 26) are also of interest, especially for the higher power tests.

Coal and Combustible (Table V).—Attention has been called to the very large amount of water evaporated by the boiler tested. It follows that a correspondingly large amount of fuel is needed to bring about this evaporation. The record appears in Table V.

The coal used for all tests was Indiana block, mined in the neighborhood of Brazil. It burns to a white ash without clinkers and is light and friable. These latter qualities prevent its giving maximum results in locomotive service. The composition of several representative samples proved to be as follows:

	1	2	3	4
Per cent. fixed carbon	49.65	51.84	51.09	51.59
Per cent. volatile matter	40.29	39.00	38.93	38.87
Per cent. combined moisture	3.15	3.62	2.35	3.44
Per cent. ash	6.91	5.54	7.63	6.10
	100.00	100.00	100.00	100.00

TABLE V.—COAL AND COMBUSTION.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.			Duration of test in minutes.	Fuel. Indiana, Brazil, block coal. Pounds.					Rate of combustion.	
Consecutive number.	Laboratory designation.	Date of test.		Total dry coal fired.	Total refuse caught in ash pan.	Total combustible by analysis.	Dry coal fired per hour.	Combustible fired per hour.	Dry coal fired per square foot of grate surface per hour.	Dry coal fired per square foot of heating surface per hour.
1	2	3	4	27	28	29	30	31	32	33
1...	15—1—*A*	Dec. 12, 1894	240	3,399	292	3,059	850	765	49.3	.700
2...	15—1b—*V*	Nov. 23, 1894	190	2,577	261	2,319	814	732	47.2	.670
3...	15—1—*H*	Dec. 9, 1896	180	2,375	240	2,138	792	713	45.9	.652
4...	25—1—*A*	Dec. 14, 1894	255	3,864	93	3,478	909	818	52.8	.748
5...	15—1—*G*	Nov. 9, 1896	180	2,678	262	2,410	893	803	51.8	.735
6...	15—2—*A*	Nov. 13, 1895	180	3,297	258	2,967	1,099	989	63.7	.905
7...	25—1—*V*	Nov. 26, 1894	240	4,460	320	4,014	1,115	1,003	64.6	.918
8...	35—1—*A*	Dec. 17, 1894	180	3,785	299	3,406	1,262	1,135	73 1	1.038
9...	35—2—*F*	Jan. 21, 1895	180	3,859	295	3,473	1,286	1,158	74.6	1.059
10...	35—1—*V*	Dec. 7, 1894	140	3,180	272	2,862	1,363	1,227	78.9	1.122
11...	35—2—*E*	Jan. 16, 1895	180	4,107	353	3,696	1,369	1,232	79.3	1.127
12...	45—1—*A*	Nov. 20, 1895	150	3,272	231	2,945	1,309	1,178	75.9	1.078
13...	35—2—*B*	Jan. 14, 1895	170	4,370	461	3,933	1,542	1,388	89.4	1.270
14...	55—1—*A*	Nov. 25, 1895	120	2,980	220	2,682	1,490	1,341	86.4	1.227
15...	35—1—*H*	Dec. 18, 1896	160	4,152	320	3,737	1,557	1,401	90.3	1.283
16...	35—1—*G*	Nov. 20, 1896	170	4,288	342	3,859	1,513	1,362	87.7	1.246
17...	35—1b—*G*	Dec. 2, 1896	170	4,150	380	3,735	1,465	1,318	84.9	1.206
18...	25—2—*A*	Oct. 25, 1895	180	4,826	25	4,343	1,609	1,448	93.3	1.324
19...	55—1—*V*	Dec. 18, 1895	120	3,330	239	2,997	1,665	1,478	96.5	1.371
20...	35—2b—*H*	Feb. 10, 1897	160	4,321	332	3,889	1,620	1,458	93.9	1.334
21...	55—1—*H*	Feb. 11, 1897	120	3,203	214	2,883	1,602	1,441	92.8	1.319
22...	55—1—*G*	Nov. 23, 1896	120	3,769	241	3,392	1,885	1,696	109.2	1.552
23...	15—9—*A*	Nov. 6, 1896	150	5,014	265	4,513	2,006	1,805	116.3	1.651
24...	15—9—*H*	Dec. 11, 1896	180	6,363	344	5,727	2,121	1,909	123.0	1.746
25...	35—2—*A*	Dec. 19, 1894	180	5,933	258	5,339	1,978	1,780	114.6	1.628
26...	35—3—*G*	Dec. 4, 1896	140	4,708	365	4,237	2,018	1,816	117.0	1.662
27...	15—9—*G*	Nov. 12, 1896	160	5,487	354	4,938	2,058	1,852	199.3	1.694
28...	35—3—*H*	Dec. 14, 1896	120	4,248	346	3,823	2,124	1,912	123.2	1.749
29...	35—2—*G*	Nov. 13, 1896	160	6,183	363	5,565	2,319	2,087	134.4	1.909
30...	35—2—*H*	Dec. 16, 1896	120	4,250	297	3,823	2,125	1,912	123.2	1.750
31...	45—2—*A*	Nov. 18, 1895	140	5,720	243	5,148	2,452	2,206	142.1	2.019
32...	25—3—*A*	Nov. 1, 1895	122.5	4,684	91	4,216	2,294	2,065	133.0	1.889
33...	35—2—*C*	Jan. 23, 1895	120	5,356	384	4,820	2,678	2,410	155.3	2.205
34...	55—2—*A*	Nov. 22, 1895	68	2,905	205	2,643	2,695	2,378	153.2	2.176
35...	35—3—*A*	Nov. 15, 1895	120	6,266	298	5,639	3,133	2,819	181.6	2.158

In each test the coal was weighed—a barrowful at a time—as it was dumped at the feet of the fireman. A sample of from 50 to 100 pounds was put into a large galvanized-iron pan, and air dried. From results thus obtained, the total weight of coal fired was corrected for accidental moisture, giving results which appear in column 27. As the coal was stored under roof, the correction was always small.

The total weight of dry coal fired, as given for the several tests (column 27), contains two variables—the length of the test and the rate of combustion. The values given as dry coal fired per hour (column 30) eliminate the first variable, and supply a true basis from which to compare the rates of combustion incident to the several tests. It will be seen that the amount of coal fired per hour is between the limits of 729 pounds and 3,133 pounds. Five tests have a rate of less than ½ a ton per hour, and twelve have a greater rate than 1 ton per hour. The rate per square foot of grate per hour (column 32) ranges from 49 to 182, values—the significance of which appears when it is considered that in naval service, under forced draft, the rate seldom exceeds 60 pounds per hour. The coal burned per foot of heating surface per hour (column 33) varies from .7 to 2.6 pounds.

The amount of refuse caught in the ash pan (column 28) is an item of no great importance in the case of locomotive boilers, since a large amount of non-combustible material which would, under the conditions of stationary practice, lodge in the ash pan, is, in locomotive service, thrown out at the top of the stack. The proportion of the whole amount of ash contained by the fuel which appears in the ash pan depends upon the force of the draft, or, in other words, upon the rate of power at which the boiler is worked. It is greatest when the rate of combustion is least. When the engine is worked at very high power, the amount of refuse in the ash pan—with the light fuel employed in the tests under consideration—is almost negligible.

In stationary practice the total combustible (column 29) is obtained by subtracting the weight of refuse from the weight of coal. For reasons already explained, such a process gives no useful result when applied to the tests of locomotive practice. For the present purpose, therefore, resort has been had to the chemical analysis of the fuel, which shows about one-tenth the weight of the dry coal to be non-combustible. The total combustible is therefore assumed to equal nine-tenths of the weight of dry coal fired. The combustible per hour on this basis is shown as column 31.

Thermal Units (Table VI).—The thermal units imparted to each pound of water passing the boiler, or

$$Q = xr + q - q_0,$$

is given in column 33. The rate at which heat is transferred, as indicated by the thermal units absorbed by the water of the boiler each minute, is given in column 34, while the thermal units absorbed per pound of dry coal burned are given in column 35, and per pound of combustible in column 36.

TABLE VI.—THERMAL UNITS.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.			Duration of test in minutes.	British thermal units. Assuming steam to have the quality as shown by column 16.			
Consecutive number.	Laboratory designation.	Date of test.		Per pound of steam generated.	Total per minute.	Per pound of dry coal.	Per pound of combustible.
1	2	3	4	33	34	35	36
1	15—1—*A*	Dec. 12, 1894	240	1,164.1	107,194	7,569	8,410
2	15—1½—*V*	Nov. 23, 1894	190	1,162.6	108,858	8,026	8,918
3	15—1—*H*	Dec. 9, 1896	180	1,152.4	116,668	8,842	9,823
4	25—1—*A*	Dec. 14, 1894	255	1,160.0	117,798	7,774	8,638
5	15—1—*G*	Nov. 9, 1896	180	1,158.6	120,340	8,088	8,988
6	15—2—*A*	Nov. 13, 1895	180	1,160.2	140,778	7,686	8,541
7	25—1—*V*	Nov. 26, 1794	240	1,161.8	142,688	7,678	8,531
8	35—1—*A*	Dec. 17, 1894	180	1,161.7	157,268	7,479	8,310
9	35—2—*F*	Jan. 21, 1895	180	1,165.1	157,502	7,348	8,163
10	35—1—*V*	Dec. 7, 1894	140	1,164.7	165,546	7,288	8,098
11	35—2—*E*	Jan. 16, 1895	180	1,164.1	166,188	7,283	8,093
12	45—1—*A*	Nov. 20, 1895	150	1,158.1	167,336	7,671	8,523
13	35—2—*B*	Jan. 14, 1895	170	1,160.5	167,624	6,521	7,245
14	55—1—*A*	Nov. 25, 1895	120	1,154.7	172,079	6,729	7,699
15	35—1—*H*	Dec. 18, 1896	160	1,155.3	178,516	6,879	7,643
16	35—1—*G*	Nov. 20, 1896	170	1,156.5	180,706	7,164	7,961
17	35—1½—*G*	Dec. 2, 1896	170	1,157.4	182,072	7,458	8,287
18	25—2—*A*	Oct. 25, 1895	180	1,158.2	185,994	6,937	7,709
19	55—1—*V*	Dec. 18, 1895	120	1,156.3	187,109	6,743	7,492
20	35—2½—*H*	Feb. 10, 1897	160	1,162.0	187,260	6,934	7,704
21	55—1—*H*	Feb. 11, 1897	120	1,158.5	198,046	7,419	8,243
22	55—1—*G*	Nov. 23, 1896	120	1,156.1	200,015	6,369	7,076
23	15—9—*A*	Nov. 6, 1896	150	1,157.2	220,038	6,583	7,314
24	15—9—*H*	Dec. 11, 1896	180	1,156.6	220,866	6,248	6,942
25	35—2—*A*	Dec. 19, 1894	180	1,159.3	221,072	6,707	7,452
26	35—3—*G*	Dec. 4, 1896	140	1,154.8	223,206	6,637	7,375
27	15—9—*G*	Nov. 12, 1896	160	1,157.0	223,243	6,510	7,234
28	35—3—*H*	Dec. 14, 1896	120	1,155.9	225,266	6,363	7,071
29	35—2—*G*	Nov. 13, 1896	160	1,154.6	237,025	6,134	6,815
30	35—2—*H*	Dec. 16, 1896	120	1,153.5	237,746	6,713	7,459
31	45—2—*A*	Nov. 18, 1895	140	1,155.9	240,262	5,881	6,534
32	25—3—*A*	Nov. 1, 1895	212.5	1,158.8	249,743	6,531	7,256
33	35—2—*C*	Jan. 23, 1895	120	1,166.7	252,873	5,666	6,296
34	55—2—*A*	Nov. 22, 1895	68	1,153.9	269,996	6,130	6,812
35	35—3—*A*	Nov. 15, 1895	120	1,156.3	287,871	5,513	6,126

No attempt has been made to express in numerical terms the thermal efficiency of the boiler. The determination of such a value depends upon the heating value of the fuel, which is not known in precise terms. It is probably not far from 13,000 thermal units per pound of dry coal. Comparing this value with the number of thermal units taken up by the water of the boiler for each pound of coal burned (column 35), an approximate estimate of the thermal efficiency of the boiler may be had.

While the facts presented by this table are especially for the convenience of those who may desire to compare the performance of the boiler tested with data from other boilers, they are not without interest in themselves. For example, it is of interest to see that in test No. 35, the boiler transmitted approximately 288,000 thermal units per minute. That it delivered heat sufficient to raise the temperature of 144 tons of water one degree every minute. As many locomotives are now in service, having more than double the power of the one tested, it may be said that the modern locomotive is capable of delivering sufficient heat to raise 300 tons of water one degree in temperature each minute.

Draft, Rate of Combustion and Smoke-Box Temperature (Table VII).—For the present purpose, draft is defined as the difference between the pressure of the atmosphere and that of the smoke box. The draft gage consists of a U-tube, partially filled with water and securely attached to a column of the laboratory. One leg of the tube is in pipe connection with the interior of the smoke box, the opening being at the point *C*, Fig. 1, and on the axis of the boiler. Observations were made at five-minute intervals. For the tests reported the average draft (column 37) varies from 1.7 inches to 7.5 inches.

In any boiler the condition of draft determines the rate of combustion, and consequently, under ideal conditions, the draft will be a function of the rate of combustion. But under conditions actually affecting the action of the boiler of a locomotive there are variations in this relationship. The precise action of the steam jet in producing a draft action has been discussed in

TABLE VII.—DRAFT, RATE OF COMBUSTION AND SMOKE-BOX TEMPERATURE.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35, that for which it is greatest.

Identification of test.			Duration of test in minutes.	Average pressure. Draft or vacuum in smoke box. Inches of water.	Average temperature, degrees Fahrenheit, of smoke box.	Fuel: Indiana, Brazil, block coal, pounds. Dry coal fired per hour.
Consecutive number.	Laboratory designation.	Date of test.				
1	2	3	4	37	38	39
1	15—1—*A*	Dec. 12, 1894	240	1.72	553	850
2	15—1[b]—*V*	Nov. 23, 1894	190	2.04	550	814
3	15—1—*H*	Dec. 9, 1896	180	1.93	570	792
4	25—1—*A*	Dec. 14, 1894	255	1.93	567	909
5	15—1—*G*	Nov. 9, 1896	180	1.87	583	893
6	15—2—*A*	Nov. 13, 1895	180	2.42	621	1,099
7	25—1—*V*	Nov. 26, 1894	240	2.60	606	1,115
8	35—1—*A*	Dec. 17, 1894	180	3.00	628	1,262
9	35—2—*F*	Jan. 21, 1895	180	2.57	653	1,286
10	35—1—*V*	Dec. 7, 1894	140	3.43	633	1,363
11	35—2—*E*	Jan. 16, 1895	180	2.89	652	1,369
12	45—1—*A*	Nov. 20, 1895	150	2.68	644	1,309
13	35—2—*B*	Jan. 14, 1895	170	3.28	664	1,542
14	55—1—*A*	Nov. 25, 1895	120	2.58	675	1,490
15	35—1—*H*	Dec. 18, 1896	160	3.00	655	1,557
16	35—1—*G*	Nov. 20, 1896	170	3.02	685	1,513
17	35—1[b]—*G*	Dec. 2, 1896	170	2.98	618	1,465
18	25—2—*A*	Oct. 25, 1895	180	3.37	696	1,629
19	55—1—*V*	Dec. 18, 1895	120	3.20	667	1,665
20	35—2[b]—*H*	Feb. 10, 1897	160	3.18	689	1,620
21	55—1—*H*	Feb. 11, 1897	120	3.44	695	1,602
22	55—1—*G*	Nov. 23, 1896	120	3.57	...	1,885
23	15—9—*A*	Nov. 6, 1896	150	4.56	724	2,006
24	15—9—*H*	Dec. 11, 1896	180	4.99	696	2,121
25	35—2—*A*	Dec. 19, 1894	180	4.42	720	1,978
26	35—3—*G*	Dec. 4, 1896	140	4.88	719	2,018
27	15—9—*G*	Nov. 12, 1896	160	4.76	724	2,058
28	35—3—*H*	Dec. 14, 1896	120	4.52	...	2,124
29	35—2—*G*	Nov. 13, 1896	160	4.65	655	2,319
30	35—2—*H*	Dec. 16, 1896	120	4.33	...	2,125
31	45—2—*A*	Nov. 18, 1895	140	4.93	741	2,452
32	25—3—*A*	Nov. 1, 1895	122.5	5.45	762	2,294
33	35—2—*C*	Jan. 23, 1895	120	5.13	738	2,678
34	55—2—*A*	Nov. 22, 1895	68	4.58	755	2,695
35	35—3—*A*	Nov. 15, 1895	120	7.48	798	3,133

another place.* It is shown elsewhere in this paper, other things being equal, the capacity of the jet as a means for producing draft is nearly proportional to the weight of steam discharged per unit of time; that, whether the discharge is in the slow,

* Report of Committee on "Exhaust Pipes and Steam Passages." Proceedings of the American Railway Master Mechanics' Association, 1896.

heavy puffs incident to slow speed, or in lighter but more rapid impulses, is not material. If the weight of steam discharged is the same, the draft action is approximately constant. The reduction of pressure in the smoke box, however, which may result from the action of the exhaust under given conditions, depends upon the freedom with which air is permitted to pass into the fire box. If the fire is thick and solid, the draft, as determined by the reduction of pressure in the smoke box, will be high; if the fire is light, the draft will be low. The draft readings given (column 37) are the average results of operations at five-minute intervals. They may be accepted as a close approximation to the normal readings for the tests.

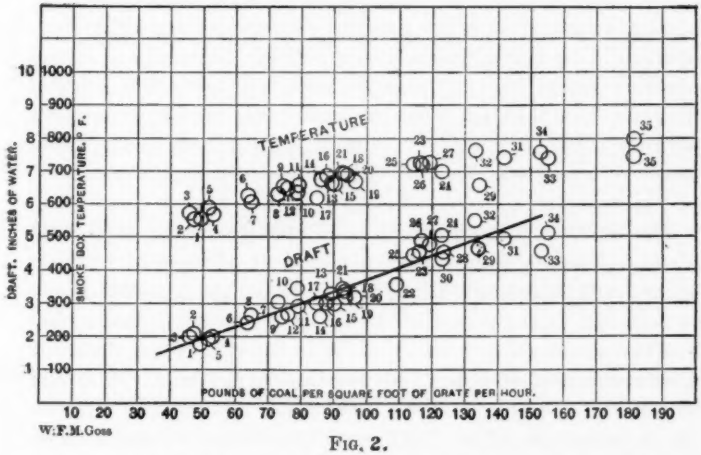


FIG. 2.

POUNDS OF COAL PER FOOT OF GRATE PER HOUR, AS RELATED TO DRAUGHT AND SMOKE-BOX TEMPERATURE.

The relation of reduction of pressure in the smoke box to coal burned per square foot of grate surface is well shown by Fig. 2, and the relation of pressure reduction in smoke box, and evaporation per square foot of heating surface by Fig, 3. The first diagram (Fig. 2) represents the effect of changes in the draft condition on combustion, and the second (Fig. 3) upon the evaporative power of the boiler. In both diagrams, for reasons

already in part explained, the points representing individual tests fall irregularly. An approximation to the mean curve, representing draft and rate of combustion, is shown by the straight line (Fig. 2) which is represented by the equation,

$$D = .037G, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which D is the draft in inches of water, and G is the pounds of coal per square foot of grate per hour.

Smoke-box temperatures were determined by the use of a copper ball of known weight which was lodged in the center of the smoke box (B, Fig. 1) until its temperature had become equal to that of the surrounding gases. It was then allowed to roll quickly down an inclosed tube into a water calorimeter, the original temperature of the ball being calculated from data thus obtained. By these means it was possible ordinarily to obtain one observation for each hour's duration of test. For some of the later tests a La Chatelier pyrometer was used in connection with the copper ball, and still more recently has been exclusively depended upon, but all of the data presented is from the copper-ball calorimeter.

The smoke-box temperature, as affected by changes in the rate of combustion is shown by Fig. 2, and as affected by changes in the rate of evaporation by Fig. 3. From these figures it will be seen that as the power of the boiler is increased the smoke-box temperature rises; also that, as in the case of the draft, the points representing individual tests fall irregularly. It should be noticed, however, that the smoke-box temperature (column 38) is lower than it is usually assumed to be. It varies from 550 degrees to 798, a range which, considering the variation in the rate of combustion (column 39), is not great. Ideal conditions should make the smoke-box temperature a function of the rate of combustion, but under actual conditions the relationship, as it appears in Fig. 2, is not without variation. This is unquestionably due to differences in fire condition, the efficiency of the action at the grate varying greatly for different tests. Other things being equal, a low smoke-box temperature should be expected to indicate a thin fire.

Smoke-box temperatures, plotted with evaporation, are given in Fig. 3. As evaporation is more directly a function of the heat passing the tubes than of furnace action, this comparison does not necessarily involve inequalities in the action of the grate. For this reason the points should be expected to fall more nearly in line, but at the scale chosen for the diagram it must be confessed that the actual difference is not great.

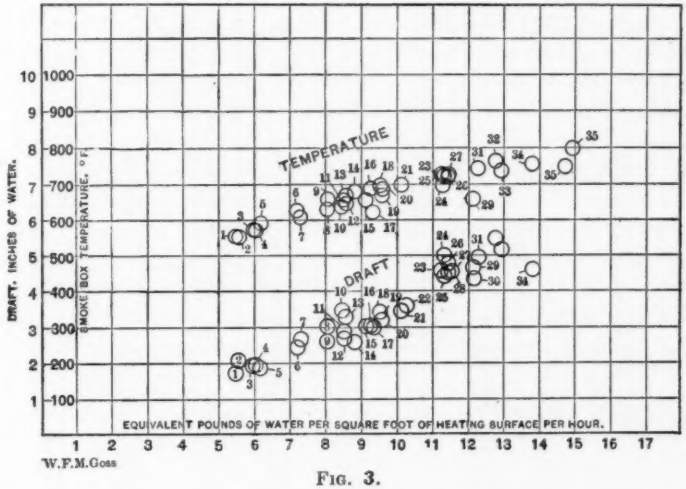


FIG. 3.

POUNDS OF WATER PER FOOT OF HEATING SURFACE PER HOUR, AS RELATED TO DRAUGHT AND SMOKE-BOX TEMPERATURE.

Evaporative Performance (Table VIII).—If it is remembered that the results of this, as of other tables, are arranged in order of power the data it presents will have increased significance. For example, by merely scanning its columns, the change in evaporative efficiency resulting from increment power may be seen. The table shows the actual evaporation per pound of dry coal (column 40) to vary from 6½ pounds of water for the lightest power test to 4.77 for the heaviest. Columns 41 and 42 show respectively the evaporation from and at 212 degrees Fahrenheit for each pound of dry coal, assuming the quality of

the steam to be that shown by the calorimeter (column 16), and assuming all steam generated to have been dry and saturated. In a similar manner columns 43 and 44 show the equivalent

TABLE VIII.—EVAPORATIVE PERFORMANCE.

The several tests represented in this table are arranged in order of the rate of evaporation, No. 1 representing the test for which the rate is least, and No. 35 that for which it is greatest.

Identification of test.				Evaporative performance.				
				Evaporation.	Equivalent evaporation from and at 212 degrees Fahrenheit.			
					Per pound of dry coal.		Per pound of combustible.	
Consecutive number.	Laboratory designation.	Date of test.	Duration of test in minutes.	Total water divided by total cost.	Assuming quality of steam as shown by column.	Assuming all water delivered to have been completely evaporated into dry steam.	Assuming quality of steam as shown by column.	Assuming all water delivered to have been completely evaporated into dry steam.
1	2	3	4	40	41	42	43	44
1...	15—1—*A*	Dec. 12, 1894	240	6.50	7.83	7.86	8.70	8.74
2...	15—1[b]—*V*	Nov. 23, 1894	190	6.90	8.31	8.35	9.24	9.28
3...	15—1—*H*	Dec. 9, 1896	180	7.67	9.15	9.26	10.17	10.29
4...	25—1—*A*	Dec. 14, 1894	255	6.70	8.05	8.10	8.95	9.00
5...	15—1—*G*	Nov. 9, 1896	180	6.98	8.37	8.44	9.31	9.38
6...	15—2—*A*	Nov. 13, 1895	180	6.63	7.95	8.00	8.84	8.89
7...	25—1—*V*	Nov. 26, 1894	240	6.61	7.95	7.99	8.84	8.88
8...	35—1—*A*	Dec. 17, 1894	180	6.44	7.74	7.99	8.61	8.66
9...	35—2—*F*	Jan. 21, 1895	180	6.31	7.61	7.66	8.45	8.51
10...	35—1—*V*	Dec. 7, 1894	140	6.26	7.54	7.58	8.38	8.42
11...	35—2—*E*	Jan. 16, 1895	180	6.26	7.54	7.58	8.38	8.42
12...	45—1—*A*	Nov. 20, 1895	150	6.62	7.96	7.99	8.83	8.88
13...	35—2—*B*	Jan. 14, 1895	170	5.62	6.75	6.79	7.50	7.54
14...	55—1—*A*	Nov. 25, 1895	120	6.00	7.17	7.24	7.95	8.04
15...	35—1—*H*	Dec. 18, 1896	160	5.95	7.12	7.20	7.92	8.00
16...	35—1—*G*	Nov. 20, 1896	170	6.19	7.41	7.48	8.24	8.31
17...	35—1[b]—*G*	Dec. 2, 1896	170	6.44	7.72	7.80	8.58	8.66
18...	25—2—*A*	Oct. 25, 1895	180	5.99	7.18	7.23	7.98	8.04
19...	55—1—*V*	Dec. 18, 1895	120	5.83	6.98	7.03	7.76	7.81
20...	35—2[b]—*H*	Feb. 10, 1897	160	5.98	7.18	7.25	7.97	8.05
21...	55—1—*H*	Feb. 11, 1897	120	6.40	7.68	7.75	8.54	8.62
22...	55—1—*G*	Nov. 23, 1896	120	5.51	6.59	6.66	7.33	7.40
23...	15—9—*A*	Nov. 6, 1896	150	5.69	6.81	6.86	7.57	7.63
24...	15—9—*H*	Dec. 11, 1896	180	5.40	6.47	6.53	7.18	7.26
25...	35—2—*A*	Dec. 19, 1894	180	5.79	6.94	7.00	7.72	7.78
26...	35—3—*G*	Dec. 4, 1896	140	5.75	6.87	6.95	7.63	7.73
27...	15—9—*G*	Nov. 12, 1896	160	5.63	6.74	6.80	7.49	7.56
28...	35—3—*H*	Dec. 14, 1896	120	5.50	6.59	6.65	7.32	7.39
29...	35—2—*G*	Nov. 13, 1896	160	5.31	6.35	6.42	7.06	7.13
30...	35—2—*H*	Dec. 16, 1896	120	5.82	6.95	7.03	7.73	7.81
31...	45—2—*A*	Nov. 18, 1895	140	5.09	6.09	6.14	6.77	6.83
32...	25—3—*A*	Nov. 1, 1895	122.5	5.64	6.76	6.82	7.51	6.57
33...	35—2—*G*	Jan. 23, 1895	120	4.86	5.86	5.90	6.52	6.55
34...	55—2—*A*	Nov. 22, 1895	68	5.31	6.34	6.40	7.04	7.11
35...	35—3—*A*	Nov. 15, 1895	120	4.77	5.71	5.76	6.36	6.39

evaporation per pound of combustible, assuming the quality of steam to be that shown by column 16, and assuming the quality to be that of dry saturated steam respectively. All of these values are proportional to the evaporative efficiency of the boiler.

Referring to the equivalent evaporation per pound of coal as it would ordinarily be calculated (column 41), it will be seen that for the lightest power test the evaporation was 7.83 pounds of coal, and that it is diminished greatly, but somewhat irregularly, as the rate of evaporation increases, until, when the power of the boiler becomes maximum, it is reduced to 5.71, a loss of 27 per cent. The equivalent evaporation per pound of coal for the several tests (column 41) and the rate of evaporation, as represented by the pounds of water evaporated per foot of heating surface per hour (column 21), are plotted in Fig. 4. From the points of this diagram an effort has been made to locate a curve which should show the relation of the evaporative efficiency to the rate of evaporation. The method adopted may be described as follows:

The several points were separated into nine groups, those of each group representing tests of nearly the same power. The grouping is as follows:

1st Group.	*2d Group.*	*3d Group.*	*4th Group.*	*5th Group.*
Test 1	Test 6	Test 8	Test 15	Test 21
" 2	" 7	" 9	" 16	" 22
" 3		" 10	" 17	
" 4		" 11	" 18	
" 5		" 12	" 19	
		" 13	" 20	
		" 14		

6th Group.	*7th Group.*	*8th Group.*	*9th Group.*
Test 23	Test 29	Test 34	Test 35
" 24	" 30		
" 25	" 31		
" 26	" 32		
" 27	" 33		
" 28			

The centers of the first seven groups have been determined and their location is shown on the diagram by solid black spots. A straight line drawn as nearly as possible through the points

thus located is assumed to show the relationship sought. There are but two centers of groups that are as much as 1 per cent. away from this line, and four touch it within one-tenth of one per cent.

Before attempting a more critical examination of the line thus located, we may inquire why so many of the points representing individual tests and shown upon the diagram by light circles fall at so great a distance from it. The facts in the case are as follows:

11	points or	31	per cent.	of the whole	agree	with the	curve	within	1 per cent.
15	"	43	"	"	"	"	"	2	"
18	"	51	"	"	"	"	"	3	"
21	"	60	"	"	"	"	"	4	"
24	"	69	"	"	"	"	"	5	"
27	"	77	"	"	"	"	"	6	"

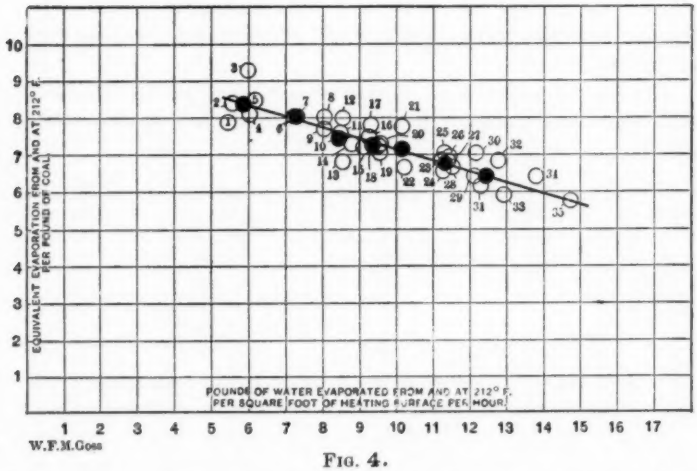

EQUIVALENT EVAPORATION FROM AND AT 212° F. PER POUND OF COAL
POUNDS OF WATER EVAPORATED FROM AND AT 212° F. PER SQUARE FOOT OF HEATING SURFACE PER HOUR
W.F.M.Goss

FIG. 4.

RATE OF EVAPORATION AND EFFICIENCY, AS SHOWN BY POUNDS OF WATER PER FOOT OF HEATING SURFACE PER HOUR AND POUNDS OF WATER PER POUND OF COAL.

There is a widespread feeling among motive-power men that the character of the exhaust has much to do with the efficiency of the furnace action; that a heavy exhaust incident to slow run-

ning will have a different effect upon the fire than the lighter but more rapid action attending higher speeds, though the draft, as registered by a gage in the smoke box, may read the same. It was but natural, therefore, to first look to the engine conditions for an explanation of the irregularities in the efficiency of the boiler. The result of such a study tends to disprove the commonly-accepted theory, and justifies the conclusion that, with a given vacuum in the smoke box, the action of the boiler is quite independent of the manner in which the vacuum is maintained, whether by slow, heavy beats, or quicker, lighter pulsations. For example, we have tests 1, 2, 3, 4 and 5, for which differences in engine conditions were confined to the dimensions or the setting of the valves. All were run at a speed of fifteen miles an hour, and all at shortest cut-off, and yet the results are widely separated. In the second group are tests 6 and 7, which check each other closely, but one was run at low speed under a liberal cut-off (15—2), while the other was at a higher speed and shorter cut-off (25—1). The third group consists of tests 8 (35—1—*A*), 9 (35—2—*F*), 10 (35—1—*V*), 11 (35—2—*E*), 12 (45—1—*A*), 13 (35—2—*B*) and 14 (55—1—*A*). Tests number 8, 9, 10 and 11, all at thirty-five miles an hour, two having short cut-off and two a more liberal one, all fall near the curve.

Of the fourth group, including tests 15 (35—1—*H*), 16 (35—1—*G*), 17 (35—1_b—*G*), 18 (25—2—*A*), 19 (55—1—*V*), 30 (35—2_b—*H*), tests 16, 18 and 20, which differ one from the other in speed and cut-off, fall most nearly upon the curve, while tests 15 and 16, having the same condition, fall on the opposite side. The fifth group contains two tests 21 (55—1—*H*) and 22 (55—1—*G*), both at the same high speed and short cut-off, fall on either side of the line curve. A comparison of the remaining groups gives similar results. It seems, therefore, but fair to conclude that variations in the character of the exhaust jet—such as result from changes in speed or cut-off—do not in themselves affect the efficiency of the boiler.

It is well known that, when an engine is working under a light load, a skillful fireman can maintain a very thin fire over the whole grate. Under favorable conditions one may almost

see the grate bars through the fire. All portions of such a fire are bright, and there will be plenty of steam, but the firing must be frequent. Such a fire offers so little resistance to the incoming air that larger volumes than are needed for combustion pass through the furnace and absorb a portion of its heat. Again, the fire may be made so thick that it will not burn clear. The demand for steam may not be great, and a sluggish and smoky fire may serve to generate it. But such conditions cannot give maximum efficiency. It follows that somewhere between the very thin fire and the very thick fire will be one of such thickness as will result in maximum efficiency. The same fireman served for all tests here reported. He was skilled in his work, and every effort was made to have a fire suited to the demands made upon it. But the locomotive fireman takes his cue from the steam gage rather than from the furnace. If the finger of the gage is moving upward, or holds its own, the fire is usually assumed to be all right; if it falls, something must be done. The actual condition of the fire under such circumstances, especially in a test for which a constant speed and load are maintained, depends very much upon the character of the fire at the start. It may happen that two tests, apparently identical as to speed, load, etc., may be run, one with a thick fire and the other with a comparatively thin fire, and, so far as outward conditions are concerned, the tests may seem equally satisfactory, while neither satisfy conditions for maximum efficiency.

With these facts in mind, we may now inquire further concerning the variations in the results of tests to which attention has already been directed. Thus a comparison of the eleven tests that agree with the mean curve (Fig. 4) within 1 per cent. with the eleven tests which have the greatest divergence from it, reveals the fact that the tests of the latter class are, for the most part, those in which the firing of the boiler was difficult. The greater part of the tests of this group are either tests at very low power, for which only a light fire could be maintained without danger of losing steam at the safety valve, or tests at high speeds, when the work of firing was hard and difficult. Included in this group also is one test under low boiler pressure, which

is to be regarded as a light-power test. On the other hand, those which agree most nearly with the curve are, for the most part, tests at medium load, which were easily fired. An exhibit of these facts is as follows:

Results in agreement with curve.					Results which diverge from the curve.				
Distance which points are off the curve.	Test number.	Laboratory designation.			Distance which points are off the curve.	Test number.	Laboratory designation.		
Per cent.		Speed.	Cut-off.	Series.	Per cent.		Speed.	Cut-off.	Series.
0	6	15	2	*A*	10.6	13	35	2	*B*
0.2	35	35	3	*A*	9.9	3	15	1	*H*
0.3	11	35	2	*E*	8.5	21	55	1	*H*
0.4	7	25	1	*V*	7.9	1	15	1	*A*
0.4	10	35	1	*V*	7.4	32	25	3	*A*
0.5	8	35	1	*A*	7.3	30	35	2	*H*
0.7	23	15	9	*A*	6.5	22	55	1	*G*
0.8	27	15	9	*G*	6.2	33	35	2	*C*
0.9	20	35	2b	*H*	5.8	34	55	2	*A*
0.9	16	35	1	*G*	5.4	31	45	2	*A*
0.9	2	15	1b	*V*	5.3	12	45	1	*A*

Accepting the experimental results as reliable, it seems safe to conclude that variations in the efficiency of the boiler, as disclosed by different tests at the same power, are due to irregularities in the character of firing.

Power and Efficiency.—Referring again to Fig. 4, it should be noted that the ordinates in this diagram represent the evaporative efficiency of the boiler, and the abscissæ the rate of evaporation. The manner in which the line which is assumed to represent the mean of these points was drawn has already been described. The equation for the line is

$$E = 10.08 - .296H, \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which E is the pounds of water evaporated from and at 212 degrees per pound of coal, and H the pounds evaporated per square foot of heating surface per hour.

This equation and others derived from it are assumed to represent the average performance of the boiler when using Indiana block coal. By its use it is possible to obtain a coal record from the water rate, no weighing being done of the fuel as consumed. Defence for such a practice is to be found in the comparative

ease with which the water record is obtained, and in the fact that the coal consumption, as determined from the equation is a more consistent factor than can ordinarily be obtained experimentally from a few tests. The form of the equation will doubtless hold for all boilers of similar design with that tested, but the constants may change with the proportions of the boiler, and will of necessity change with the character of the fuel employed.

Efficiency as Affected by the Quality of Fuel.—While apparently somewhat apart from the present purpose, it will be of interest in connection with the general discussion to review certain results which have been obtained from five different samples of fuel tested in the same boiler, and which were reported in a paper presented to the Western Railway Club at the December meeting, 1898. The several samples were designated as *A*, *B*, *C*, *D*, and *E*. All were bituminous coals. The evaporation obtained from each of these samples is shown by Fig. 5. Line *D* on the diagram very nearly corresponds with that given in Fig. 8 for the Indiana block, and its equation is substantially that given above. The equation for line *E*, representing the best coal, may be taken as

$$E_1 = 12.9 - 0.41\ H, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

and for line *C*, representing the poorest coal, as

$$E_2 = 9.4 - 0.24\ H. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

These equations probably represent the range of variations in performance, as affected by different qualities of fuel.

The rate of evaporation represented by the experiments with the Indiana block, upon which equation 1 is based, lies between the limits of 5 and 15 pounds of water per foot of heating surface per hour, while the limits on which equations *a* and *b* are based are but little narrower. The equations, then, are reliable when *H* is allowed a value which is not less than 5 nor greater than 15.

In this connection it is of interest to note that the lines *E*, *A*, *B*, *C*, *D* converge, and it may be assumed that if *D* and *C* were sufficiently extended they would meet; that is, if the rate of

evaporation were made sufficiently high, both the good and the poor coal would give the same evaporation. The point where this would happen can be determined from equations *a* and *b* by making E equal to E_2. Thus,

$$12.9 - 0.41H = 9.4 - 0.24H$$

and

$$H = 20. \text{ approximately.}$$

That is, accepting for the moment this equation as true for all values of H, they show that when the boiler is forced to evapo-

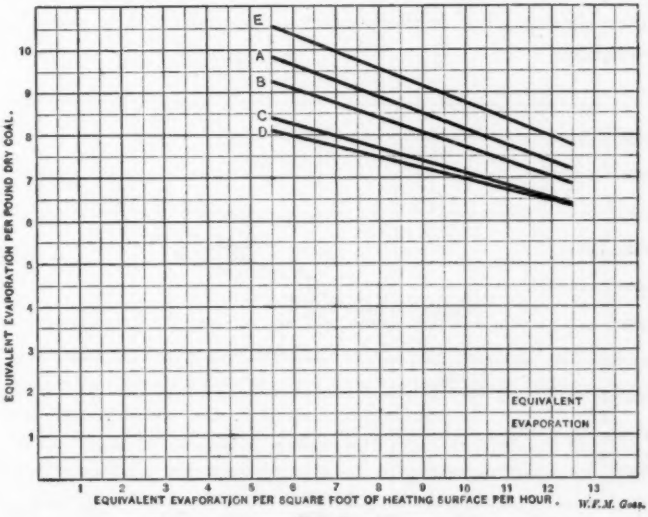


FIG. 5.

RATE OF EVAPORATION AND EFFICIENCY FOR FIVE DIFFERENT SAMPLES OF BITUMINOUS COAL.

rate 20 pounds of water per foot of heating surface per hour, the poorer coal will evaporate as much water per pound as the better. It is evident that the equations are not to be relied upon for conditions so widely separated from those covered by the experiments, and it is equally evident that the boiler could not be forced to so high a rate of evaporation. The general

conclusion to be deduced is, however, perfectly logical. The higher the power to which a boiler is forced, the smaller is the fraction of the total heat developed which can be absorbed by the heating surface. If forced to very high power, the amount of heat utilized out of all that is available becomes so small that slight variations in the amount available do not measurably affect the amount utilized.

If carried to extreme limits it will doubtless appear that the line represented by equation 2, Fig. 4, is in fact not strait, though, within limits which are sufficiently broad to cover all practical cases, it may probably be so considered. The form of this, and other similar lines, is the subject of discussion in a preceding paragraph.

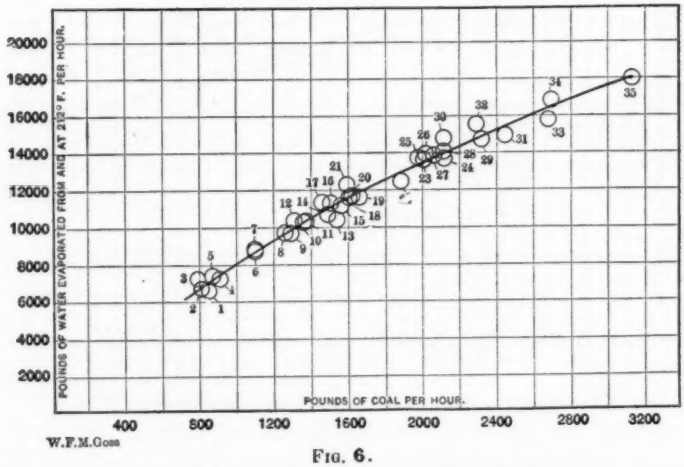


FIG. 6.

COMBUSTION AND EVAPORATION, AS SHOWN BY TOTAL POUNDS OF COAL PER HOUR AND TOTAL POUNDS OF WATER PER HOUR.

Derived Relations.—The relation between the rate of evaporation and the rate of combustion for the thirty-five tests under discussion is shown by Fig. 6. The points in this figure are located from experimental data, but the curve which is assumed

to represent their mean value was plotted from its equation as derived from equation 2. Thus, equation 2 as already given is

$$E = 10.08 - .296H. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

We may let

W = total pounds of water evaporated, from and at 212 degrees per hour,

and

C = total pounds of coal fired per hour.

We may note also that

1,214.4 = square feet of heating surface in the experimental boiler.

Then

$$\frac{W}{C} = E, \text{ and } H = \frac{W}{1{,}214};$$

or

$$\frac{W}{C} = 10.08 - 0.296H$$

$$= 10.08 - \frac{0.266W}{1{,}214.4},$$

and

$$C = \frac{W}{10.08 - 0.000244W}. \quad . \quad . \quad . \quad . \quad (3)$$

It is from this equation that the curve (Fig. 6) was plotted. It will be seen that, while the curve is derived quite independently of the points, the two systems agree closely.

The relation of water evaporated per pound of coal, and pounds of coal consumed per foot of grate per hour, is shown by Fig. 7.

This curve, in common with the one preceding, is plotted from its equation, which was obtained as follows:

Having

$$E = 10.08 - 0.296H, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

let

G = pounds of coal per square foot of grate per hour.

Note that

17.25 = square feet of grate surface for the experimental boiler.

It has already been shown that

$$\frac{W}{C} = 10.08 - \frac{0.296}{1{,}214.4} W,$$

or

$$\frac{W}{C} + .000244 \frac{W}{C} - C = 10.08;$$

but

$$\frac{W}{C} = E,$$

therefore

$$E + 0.000244EC = 10.08,$$

and

$$E = \frac{10.08}{1 + 0.000244} C.$$

But

$$C = 17.25G,$$

and, therefore,

$$E = \frac{10.08}{1 + .00421G}. \quad \ldots\ldots\ldots \quad (4)$$

The agreement between the curve plotted from this equation and the experimental points is close in this case (Fig. 7) as in those previously discussed. Other relationships may be established by aid of those already given. Perhaps the most interesting is that of draft (D) to total weight of water evaporated per hour (W), which takes the form of

$$D = \frac{.00214W}{10.08 - .000244W}. \quad \ldots\ldots \quad (5)$$

Before leaving this phase of the subject, it is of interest to note that the plotted curves representing the derived equations (Figs. 6 and 7) are based from the equation of a straight line. This straight line (Fig. 4) is believed to fairly represent the experimental points for which it stands, and it follows that the curves of Figs. 6 and 7 represent with an equal degree of accuracy the experimental points in the midst of which they are drawn. If, however, the experimental points represented by Fig. 7 had been accepted as a starting point for the several curves, a straight line might have been drawn through them

without difficulty. Had this been done and the relation represented by Fig. 4 been mathematically derived from it, the line of Fig. 4 would have been a curve. From these considerations, and from those previously presented concerning the conveyance of the several lines representing different samples of coal, it is evident that none of the relationships discussed are perfectly

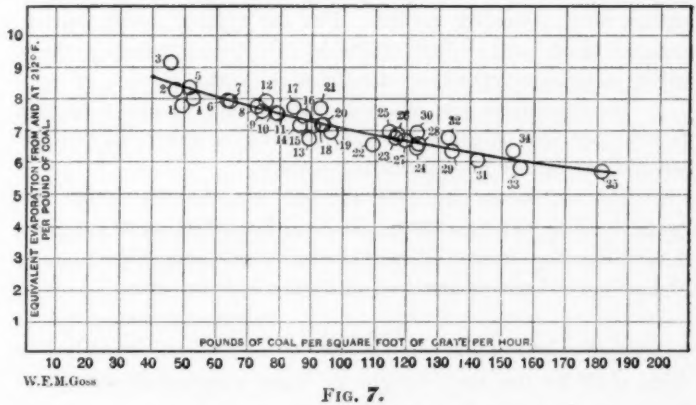


FIG. 7.

RATE OF COMBUSTION AND EFFICIENCY, AS SHOWN BY POUNDS OF COAL PER FOOT OF GRATE PER HOUR AND POUNDS OF WATER PER POUND OF COAL.

represented by a straight line. But with nothing but the experimental point as a basis, it appears difficult to locate a line which will better represent them than the straight line of Fig. 4, and, as before noted, within the limits for which it applies, such cannot be much in error.

III.—CONCLUSIONS.

1. The steam delivered by the boiler, tested under constant conditions of running, as shown by calorimeter attached to dome, is at all times nearly dry, the entrained moisture rarely equaling 1.5 per cent., and being generally much less than this. While the relationship can not be perfectly defined, it appears that the entrained moisture increases slightly as the rate of evaporation is increased.

2. The maximum power at which the boiler was worked with Brazil black coal was such as gave 30 boiler horsepower for each square foot of grate, and .427 horsepower for each square foot of heating surface. Experiments with other fuels indicate that these values may be increased by the use of a better coal by about 15 per cent., giving maximum values, which, in round numbers, are 35 horsepower per foot square of grate and .5 horsepower per square foot of heating surface. For the type of boiler experimented upon, and under conditions of constant running, these values may be accepted as near the maximum.

3. The maximum rate of combustion reached was 182 pounds of coal per foot of grate per hour, which is equivalent to 2.6 pounds per square foot of heating surface.

4. The maximum draft for any test was that for which the average value was 7.5 inches. If D is the reduction of pressure in a smoke box measured in inches of water, and G the pounds of coal burned per square foot of grate per hour, then

$$D = .037G.$$

Also, if W be the total weight of water evaporated per hour, the draft necessary to produce a given evaporation is represented by the equation,

$$D = \frac{.00214W}{10.08 - .000244W}.$$

These equations apply to the boiler tested when using Indiana block coal.

5. Smoke-box temperature ranges from 550 degrees Fahrenheit to 800 degrees Fahrenheit, values which are lower than those which are often assumed to prevail.

6. The evaporative efficiency of the boiler as affected by different rates of evaporation is expressed by the equation,

$$E = 10.08 - .296H,$$

in which E is the pounds of water evaporated from and at 212 degrees per pound of coal, and H the pounds of water evaporated from and at 212 degrees per square foot of heating surface

per hour; this for the boiler tested using Indiana block coal, and for values of H of not less than 5 or greater than 15. By different coals the constants will vary, results which are near the minimum being expressed by

$$E_{\text{min.}} = 9.4 - .024H,$$

and results near the maximum by

$$E_{\text{max.}} = 12.9 - .041H.$$

7. The evaporative efficiency of the boiler as affected by different rates of combustion is expressed by the equation,

$$E = \frac{10.08}{1 + .00421G},$$

in which E, as before, is the pounds of water evaporated from and at 212 degrees per pound of coal, and G the pounds of coal burned per foot of grate per hour; this for the boiler tested using Indiana block coal.

8. The relation of coal burned to water evaporated is expressed by the equation,

$$C = \frac{W}{10.08 - .000244W},$$

in which C is the total pounds of coal burned per hour, and W the total pounds of water evaporated from and at 212 degrees per hour; this for the boiler tested using Indiana block coal.

9. The condition of running the engines, whether with long or short cut-off, or at high or low speed, does not appear to affect the efficiency of the boiler of a locomotive, except in so far as it affects the average value of the draft.

10. The efficiency of the boiler of a locomotive, as disclosed by two different tests, for which all conditions of running are the same, may vary considerably, due, doubtless, to inequalities in the firing.

A REPLY TO MR. ISHERWOOD.

By B. C. Ball, Member.

In the August number of the Journal Mr. Isherwood replied at considerable length to an article of mine regarding compression in steam cylinders. His remarks on the points which I raised occupied only a small part of his paper, and the rest of it was devoted to the elaboration of a new theory on the action of steam in working cylinders.

This theory is at least original, and is very radical in its departure from well established principles. It is not my intention to discuss this new theory, and I will leave that to others. I feel called upon, however, to answer Mr. Isherwood on the two points which were the subject of my previous paper. The further discussion of these points may seem to some unnecessary, especially as the new theory of Mr. Isherwood's overshadows them in importance, if it can be substantiated, which seems to me very doubtful, to say the least.

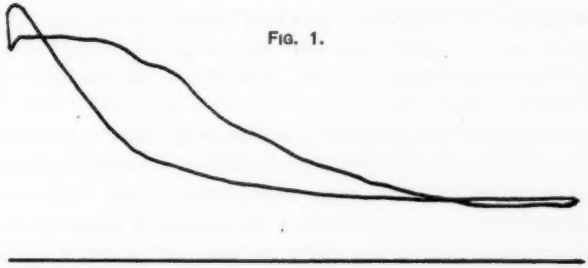
The first point in the previous discussion was in regard to the maximum possible compression of steam in the clearance spaces of an engine cylinder, and on this point Mr. Isherwood makes the following statement: "It is physically impossible to compress the back pressure in the cylinder to a pressure equal to the initial pressure in the cylinder, be the back pressure and degree of compression what they may."

Referring to this statement in his later article, he says that it is true "without any limitation or qualification."

In my previous article I denied the truth of this statement, and to back up my position I have secured some indicator diagrams which speak for themselves. These diagrams, Figs. 1 and 2, were taken from a compound engine at the testing room of the American Engine Company, and I am indebted for them

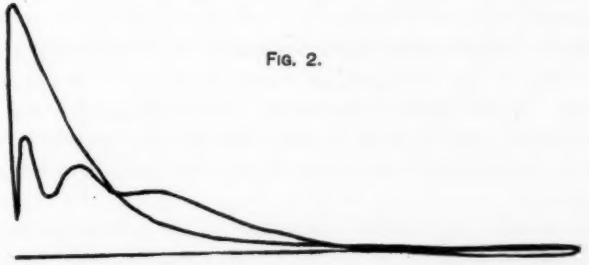
to my brother, F. O. Ball. He had a special valve fitted to this engine, and took the diagrams for me, in my presence. The engine from which the cards were taken is one of the horizontal, duplex, compound engines which the above named company has

FIG. 1.



H.P. cylinder, 11½ inches by 12 inches. Scale, 60 pounds = 1 inch.
Speed, 250 revolutions per minute. Valve set with no lead.

FIG. 2.



L.P. cylinder, 18 inches by 12 inches. Scale, 40 pounds = 1 inch.
Speed, 250 revolutions per minute. Valve set with no lead.

developed in the last few years. The high-pressure and low-pressure cylinders are placed one above the other and drive to a single crosshead. One valve performs the functions for both cylinders, and is controlled by a shaft governor.

One difficulty which arises from this arrangement, when the clearance spaces are small, is excessive compression when the load is light. To obviate this difficulty, the exhaust edges of the valve have been cut away, so that they have negative lap. The special valve which was fitted to the engine when these dia-

grams were taken was made "line and line" on the exhaust edges, and was therefore not different from ordinary slide valves in this particular. The crank was carefully placed on dead centers, and the valve set without steam lead, so Mr. Isherwood can not object to the diagrams on that score.

The indicators used were standard Tabor instruments, practically new, and as great care was used to get true and accurate cards, it will be futile for Mr. Isherwood to question their accuracy.

In view of the above facts, it would seem that some of Mr. Isherwood's remarks in the August number were somewhat unnecessary, and totally in error. It is perfectly plain, from a careful inspection of these cards, that the excess of pressure above initial pressure due to compression was not caused by the inertia of the moving parts of the indicator, but was due to the compression of the clearance steam to the pressure indicated. There being no lead, the valve does not open until the stroke is completed.

I desire to call particular attention to the low-pressure diagram, Fig. 2, the compression curve of which illustrates particularly well the point in question. It will be noticed that the compression curve rises in a practically perfect hyperbole to a pressure considerably more than double the initial pressure in the cylinder.

The second point under discussion is one which Mr. Isherwood has treated in a purely geometrical manner. Briefly stated, his position is as follows:

"First, no matter what may be the degree of expansion and compression adopted, and no matter what may be the proportion of dead space at one end of the cylinder to the capacity of the cylinder, there is neither economic gain nor loss by compression of the back pressure. In all cases, the quantity of steam compressed reproduces during the immediately succeeding stroke of the piston exactly the work of that compression.

"Second, compression does not modify in the slightest degree the injurious effect of the dead space on the economy of the steam. The injurious effect of that space remains exactly the

same, whether there be or be not compression, or what may be the degree of compression."

Mr. Isherwood tries to demonstrate this proposition geometrically, and it is on this phase of the question alone that I have taken issue with him. Whether or not compression affects in any way the *actual* economy is an entirely different proposition, and one to which I shall refer again.

Looking at the proposition from a mathematical standpoint, it becomes simply a question of maximum area of work done per unit of steam used each stroke. In my previous paper I simply referred to the formula for work done during hyperbolic expansion, $W = p_2 v_2 Log_e R$, and called attention to the fact that the work done (W) is independent of the clearance volume when this volume is filled by compression. This did not seem to appeal to Mr. Isherwood, and he seemed to think that it was merely my opinion.

To illustrate more clearly this point, and to show that this opinion has good foundation, I will apply this formula to three cases, and work out the theoretical steam consumption per horse-

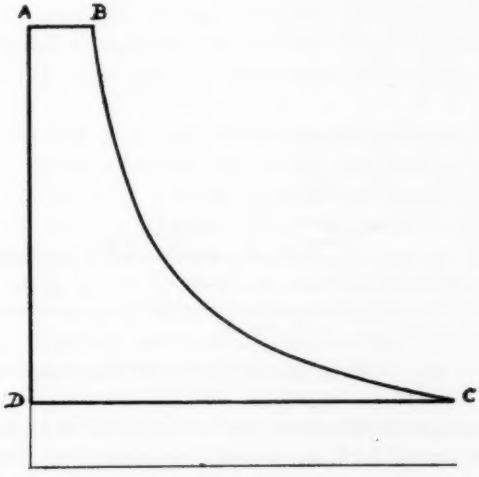


FIG. 3.

power in each case. Figs. 3, 4 and 5 will illustrate the three different cases, and in each one suppose the steam to be admitted at seven atmospheres, expanded to one atmosphere, and exhausted at that pressure.

First. Suppose the cylinder has no clearance, and one pound of steam is admitted each stroke. Fig. 3.

Work done, $W = ABCD = p_2 v_2 Log_e R$ = foot pounds of work for one pound of steam.

Where p_2 = final pressure in pounds per square foot.

v_2 = final volume of one pound of steam.

R = ratio of expansion.

Then $W = 108{,}590$; and the steam used per I.H.P. per hour is 18.2 pounds.

Second. Suppose the cylinder has clearance volume equal to $\frac{1}{14}$ of piston displacement and the cylinder contains two pounds of steam at the beginning of the stroke. The compression fills the clearance space to initial pressure, and $W = ABCD - AEFD$. Fig. 4.

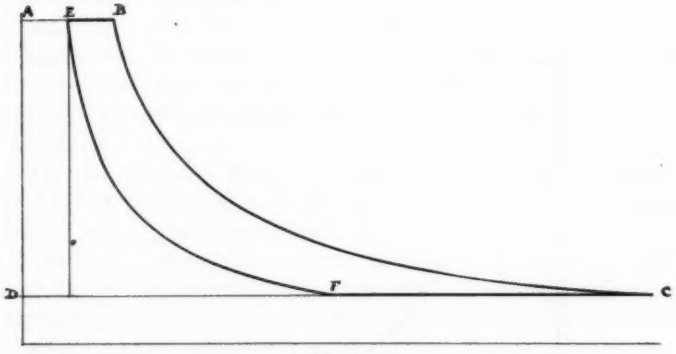


FIG. 4.

$W = 217{,}180 - 108{,}590 = 108{,}590$, and the steam used per I.H.P. per hour is 18.2 pounds.

In this case, although there are two pounds of steam in the cylinder at cut-off each stroke only one pound is used, as the other is restored by compression.

Third. Conditions same as second, except compression, there being in this case no compression. $2W = ABCD - AEFD$. Fig. 5.

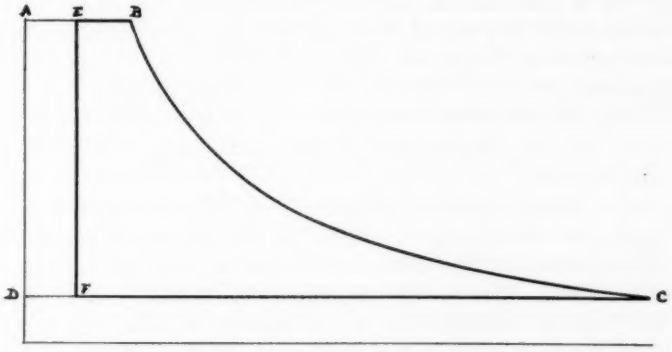


FIG. 5.

$2W = 217{,}180 - 23{,}800 = 193{,}380$.

$W = 96{,}690$, and the steam used per I.H.P. per hour is 20.5 pounds.

The total work done in this case is greater than in the last, but because there is no compression the boiler must supply two pounds of steam each stroke, and the work done (W) *per pound* is, therefore, less.

It appears from these *figures* that compression does make some difference, at least theoretically, in the economy of the steam engine, Mr. Isherwood's statement to the contrary notwithstanding. Their object is to prove two points which were stated in my last article on the subject.

First. Compression to initial pressure is essential to obtain maximum economy, if there is no condensation.

Second. If there *is* no condensation, clearance does not impair the theoretical economy, if the clearance space is filled by compression.

The extent to which these two propositions are modified by condensation will vary considerably under different conditions, but it is only a question of degree, and it is a parallel case to

expansion. Probably no one can be found who will maintain that expansion to the back-pressure line is most economical, and yet it should be, looking at it from a theoretical standpoint. It is just as absurd to say that compression does not affect steam consumption as it would be to say that expansion does not, the only difference in the two cases being the *degree* of saving, the expansion curve, of course, offering greater opportunities for saving than the compression curve, and for this reason the latter curve has been shamefully neglected, particularly in small-clearance engines.

The figures, however, disprove absolutely Mr. Isherwood's statements which I have quoted. In my last article I pointed out the fallacy of Mr. Isherwood's reasoning, and will say again that his error lies in the fact that he has reasoned in a circle. He imposes conditions as to the manner of using the steam saved by compression which make it impossible to derive the benefit from that compression, and if he will look at this subject from some different standpoint than the one he has chosen he will probably see wherein his trouble lies.

Mr. Isherwood complains that I reject the experiments of Professor Dwelshauvers-Dery as proof of his theory without understanding them. My grounds for rejecting these tests as proof are contained in Professor Dwelshauvers-Dery's report of the tests. On page 323 of the May number of the JOURNAL is the following statement:

"In the first series of ten tests without compression, the steam consumption per I H.P. varied between 10.712 kilograms and 11.526 kilograms (23.60 pounds to 25.38 pounds) a difference of 7.32 per cent.—quite an amount. We have not been able to discover the reason thereof, because without doubt the causes are very complicated, and because the lubrication of the cylinder walls plays an important part, the full influence of which it is impossible for us to appreciate.

"In the second series of ten tests at $\frac{4}{10}$ compression the variation was from 10.799 kilograms to 11.513 kilograms (23.78 pounds to 25.38 pounds) or 6.42 per cent. of the mean.

"In the third series of three tests at $\frac{6}{10}$ compression it went

from 11.091 kilograms to 11.367 kilograms (24.42 pounds to 25.02 pounds), representing 2.40 per cent. of the mean."

The variation here acknowledged, of 7.32 per cent. in the results of similar tests, is as great a difference as could be expected even under the widest variation of compression, and is therefore sufficient grounds, I think, for rejecting the tests as proof of a theory, especially as other tests have been made by equally careful experimenters which point to an entirely different conclusion.

In the actual steam engine we all know that there is more or less condensation, and various solutions of the problem of compression have been made which include in some form an allowance for this condensation. One of these is by Professor Webb, of Stevens' Institute, which can be found in the "Proceedings of the American Association for the Advancement of Science," Vol. XLII, 1893, page 119. Another is in a paper presented to the American Society of Mechanical Engineers, and can be found in Vol. XIV, page 1067, of the "Transactions."

The bone of contention has always been the *degree* of compression for best economy, no one seeming to question the fact that some compression is advantageous. Many maintain that in actual practice it is best to fill the clearance completely by compression. This view was disposed of quite conclusively by the tests of Professor Jacobus, to which I referred in my previous article, and which can be found in Vol. XV, page 915, of the "Transactions of the A. S. M. E."

STEAM TURBINES—WITH SPECIAL REFERENCE TO THE WESTINGHOUSE-PARSONS STEAM TURBINE.

[Abstract of paper read before The Engineers' Society of Western Pennsylvania.]

By Francis Hodgkinson.

The earliest records of steam engineering are to be found among the relics of Ancient Egypt. About 120 B. C. Alexandria was at the zenith of her civilization. At this time Hero, probably contemporary with Euclid and Archimedes, wrote his celebrated work "Spiritalia Seu Pneumatica." In it he described several forms of mechanical apparatus. The use of the steam jet for accelerating combustion, the expansion of air when heated in a closed vessel, several forms of steam boilers, various hydraulic apparatus for opening and closing temple doors. The most interesting among all these is described a reaction steam turbine. It consisted of a boiler, above which is a sphere mounted upon two trunnions. By means of these, steam is admitted to the interior of the sphere. On the equator were attached two bent pipes, such that the issuing steam reacted upon the sphere and caused it to revolve about its trunnions.

It is unknown whether this engine was ever more than a mechanical toy, although it is very possible it may have been used by the priests for driving so-called magical apparatus where high speed was desirable.

The next turbine capable of any practical development, and which may be regarded as the forerunner of the de Laval Turbine, was invented by Bianca in 1629. It consisted simply of a jet of steam impinging upon the vanes of a paddle wheel and blowing it around.

A century later, 1705, the reciprocating engine appeared, and

from that time until the last few years, practically nothing was done in the development of steam turbines.

Before leaving this brief historical review, it is interesting to record that Mr. Parsons, with a view of exploring the possibilitie of a reaction steam turbine, constructed one on the lines of Hero's engine. The sphere was replaced by two hollow oval sectioned arms, mounted upon a hollow shaft, with jets at the outer ends, through which steam issued tangentially to the plane of motion. The whole was enclosed within a cast-iron case and connected to a condenser.

With 100 pounds per square inch at the jets and 26 inches vacuum in the exhaust casing, a speed of 5,000 revolutions per minute was attained and 20 H.P. developed. The consumption of steam was 40 pounds per brake H.P.

It is not a little remarkable that the latest developments of steam engineering should be returning to the earliest form of engines of which we have record. It is still more remarkable that the engine, as described by Hero, had greater economy than any steam engine produced for 18 or even 20 centuries later.

The fundamental principle of the steam turbine, in contradistinction to the reciprocating steam engine, lies in the fact that the latter does work by reason of the static expansive force of the steam acting behind a piston, while in the former case the work is developed by the kinetic energy of particles of steam, which are given a high velocity by reason of the steam expanding from one pressure to a lower.

Steam turbines may he divided in to three classes:

1. Impact, of which Bianca's is an example.
2. Reaction, of which Hero's is an example.
3. A combination of both of these, of which Parsons' is an example.

It is proposed in this paper to deal only with two forms which have attained some degree of commercial success; namely, the Parsons and the de Laval, particularly the former.

The general principles made use of in water turbines also apply to steam turbines. The buckets and guides must have as little skin friction as possible, and so arranged that the acting fluid

may strike without sudden shock, and have its direction of motion changed without sharp angular deflections. One difficulty, however, presents itself, and is due to the tremendous velocity of steam as compared with that of water under ordinary heads.

The laws governing the best velocity of buckets are the same as for water wheels. In the impact turbine the ideal condition is when the peripheral velocity of the buckets is one-half that of the fluid comprising the jet. In the reaction turbine this velocity must be equal to that of the jet in order to give us this ideal condition. Now, with high-pressure steam discharging into a vacuum, the velocities obtained are from 3,000 to 5,000 feet per second, as calculated by Zeuner's formula.

A turbine, therefore, built on the lines just enumerated would have peripheral velocities far beyond the limits of strength of material. As an example, a 10-inch Hero's engine would revolve at 75,000 revolutions per minute.

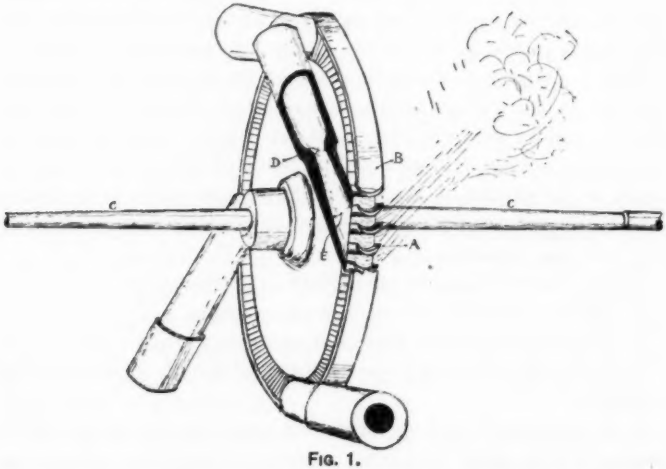


FIG. 1.

The de Laval turbine, shown on Fig. 1, consists of a divergent nozzle which directs the jet of steam upon suitably formed buckets, *A*, which are attached to the periphery of a revolving wheel. The outer edge of the buckets is shrouded by a steel

ring, *B*, which prevents the centrifugal escape of the steam. The unique features of this turbine are the nozzle, and the means by which the wheel is enabled to revolve upon its axis of gravity.

With regard to this latter point, a difficulty always arises in attempting to revolve a body at a high rotative speed. It is essential, in the first place, that the body be accurately balanced, but in spite of all care this cannot be attained with absolute accuracy. The result is that, with ordinary shaft and bearings, tremendous vibrations would be set up that would probably result in eventual rupture of the shaft. De Laval overcomes this difficulty, however, by mounting his wheel near the center of a long light shaft, *C*, capable of being considerably bent and returning to its original form. The shaft is mounted upon bearings of ordinary construction. This flexibility enables the forces set up by the revolving wheel to deflect the shaft and enable the former to revolve about its axis of gravity.

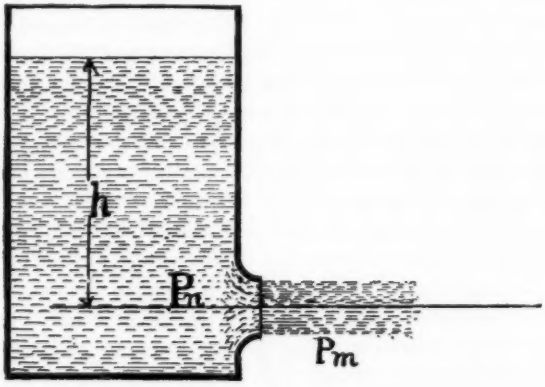
The nozzle is divergent. In it the whole expansion of the steam is carried out. The steam at the mouth of the nozzle has the same pressure as the exhaust. In other words, the steam has its energy completely transformed into mass and velocity by the time it comes in contact with the buckets.

This brings up another feature of the turbine and is, that with the exception of the nozzles and the throats of the nozzles, no parts are subjected to steam pressure. It is well known that the velocity of steam flowing through an orifice, from a greater to a lesser pressure, increases as the difference of the pressures increases, only up to a certain limit. This limit is reached when the lower pressure becomes less than $\frac{56}{100}$ths of the higher. Beyond this, however much the steam pressure is increased, the velocity of steam remains practically the same—about 1,476 feet per second. This limit of velocity is an anomaly which seems to have been never satisfactorily explained.

It is probably due to the fact the pressure in the center of the throat is not the same as in the surrounding medium. The jet, after passing the throat, suddenly expands, and the change of direction of the fluid particles gives rise to centrifugal forces. Experiments all show that a jet, discharging from a reservoir of

high pressure into a lower pressure, where the difference is greater than $\frac{56}{100}$, that the pressure in the throat of the nozzle is always equal to $\frac{56}{100}$ of the absolute pressure of the reservoir, no matter how great may be the difference between the two pressures.

The action of steam in the nozzle may be shown by further illustration.



In this case, if the reservoir were filled with water, the velocity issuing would be found by the formula $V^2 = 2gh$, where h is the actual feet head of water above the nozzle. In the case, however, of the fluid in the reservoir being steam or gas instead of water, h must be changed to an ideal head, which is the column of fluid necessary to give the given pressure at the level of the nozzle. This ideal head is equal to the feet head of water necessary to give the pressure, multiplied by the density of the water and divided by the density of the fluid in the reservoir. This formula, however, is only approximate, and is only good up to the before-mentioned limits.

With small differences of pressure, such that Pm is greater than .56 Pn, the fluid will issue with a velocity varying with the square root of the ideal head, which will increase as the differ-

ence of pressures increase until we reach the before-mentioned condition of maximum discharge, and up to this point the steam will issue from the nozzle in substantially straight lines; this, of course, providing the nozzle has a well rounded entrance, and is not a condition that might be termed "an orifice in a thin plate."

When the pressure is increased beyond this, the steam expands partially outside the nozzle, and the particles cease to issue in a straight line as before. This subsequent expansion is taken advantage of by de Laval, by means of his divergent nozzle, which is of the form shown in Fig. 1.

The throat is at D, having a well rounded entrance, and from there on the nozzle diverges. The relation of the area of the outlet at E to the area of the throat at D should satisfy the equation.

$$\frac{Fm\ Wm}{Vm} = \frac{F_2\ W_2}{V_2}$$

Fm = sectional area of the throat.
F_2 = sectional area of the outlet.
Wm = velocity of steam at throat.
W_2 = velocity of steam at outlet.
Vm = specific volume of steam at inlet.
V_2 = specific volume of steam at outlet.

This equation simply states that equal weights of steam pass at both the throat and the outlet in equal intervals of time.

Practically a nozzle must be made with the area at the exhaust end as small as possible, for the sake of getting the greatest velocity, but just so large that the pressure will not be higher than that of the exhaust pipe.

The best length of nozzle is hard to determine. If too long there will be considerable loss of velocity due to skin friction. At the same time it must be long enough to admit of proper expansion of the steam. The best shape of the divergency has been the subject of investigation by various experimenters, in order to give the best expansion curve, regarded as a single particle. The writer's opinion is that the best results in this

respect are obtained by a nozzle whose section is very near an ellipse.

The investigation of the performance of steam nozzles is particularly interesting. The apparatus usually employed is shown in Fig. 2.

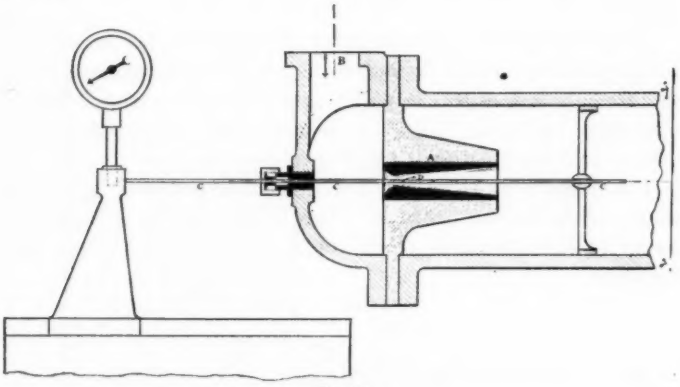


FIG. 2.

The nozzle for the experiment is at *A*, the steam entering at *B* discharges through the nozzle directly into the exhaust pipe. At *C* is provided a small searching tube, sealed at one end, and with a minute hole, *D*, some distance from this end. At the other end is provided a suitable pressure gage or mercury column. Means are provided for sliding the searching tube with its pressure gage back and forth, when pressures may be read with the hole in the searching tube in different positions throughout the length of the nozzle. From these figures a curve of pressures may be developed and from this, together with knowledge of the weight of the steam passing the nozzle per unit of time and the exact form of the nozzle, a second curve may be developed which will give some idea of the velocities of the fluid.

The curves on Fig. 3 give an example of this. They have, however, been developed theoretically on a basis of adiabatic expansion, that all the energy of the steam between the limits of pressure, viz: 150-pounds gage pressure and 26 inches

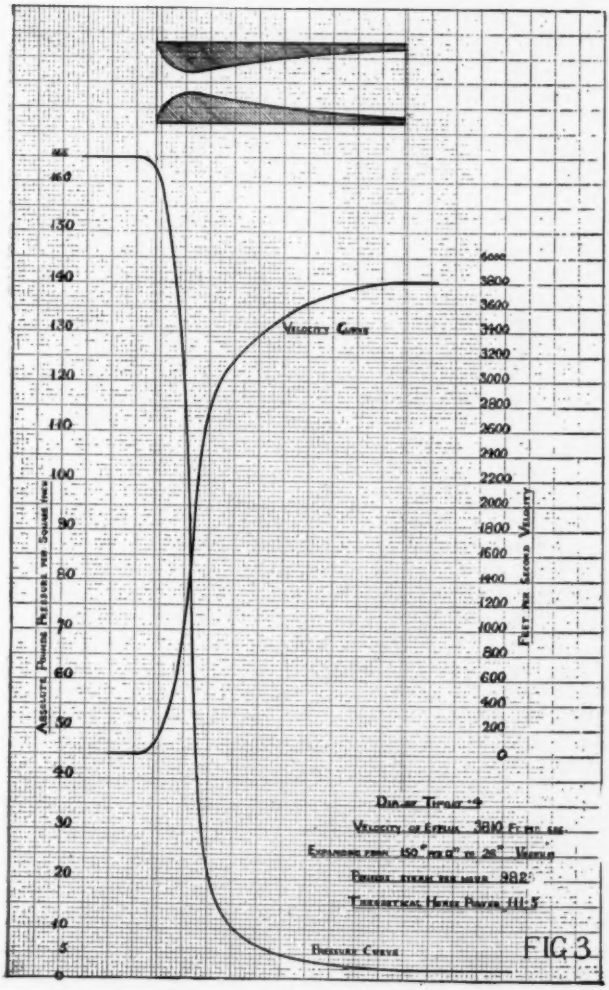

Velocity Curve
Pressure Curve
Absolute Pounds Pressure per Square Inch
Feet per Second Velocity
Diameter Throughout
Velocity of Efflux 3810 Feet per sec.
Expanding from 150 lbs per sq in to 28 in Vacuum
Pounds steam per hour 982
Theoretical Horse Power 111.5

FIG 3

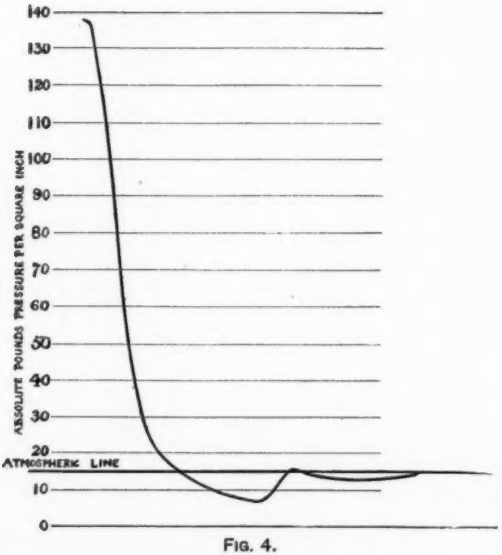


FIG. 4.

vacuum, has been converted into velocity and that there are no losses due to skin friction or through loss of pressure by low coefficient of efflux. This coefficient of efflux is a feature of the entrance to the nozzle, and varies from 50 per cent. in an orifice in a thin plate to 98 per cent. in a well-rounded orifice, as is shown in Fig. 3.

The pressure curve is an adiabatic expansion line from the throat to the outlet, and the pressure of the throat .56 times the absolute pressure of the steam before entering the nozzle.

The velocity at the mouth of the nozzle is shown to be 3810 feet per second and 982 pounds steam passing per hour—diameter of throat $\frac{4}{10}$ inch; theoretical H.P., 111.5.

In actual practice as much steam as this could not be made to pass for the reasons just given, so the nozzle would require some modification in consequence.

Of course in these investigations allowance must be made for the area of the searching tube. Fig. 4 shows an actual example of a nozzle designed for discharging into vacuum, but used for discharging into atmospheric pressure, and shows how the steam reaches near the condition of vacuum near the outlet and afterwards rises to the exhaust pressure.

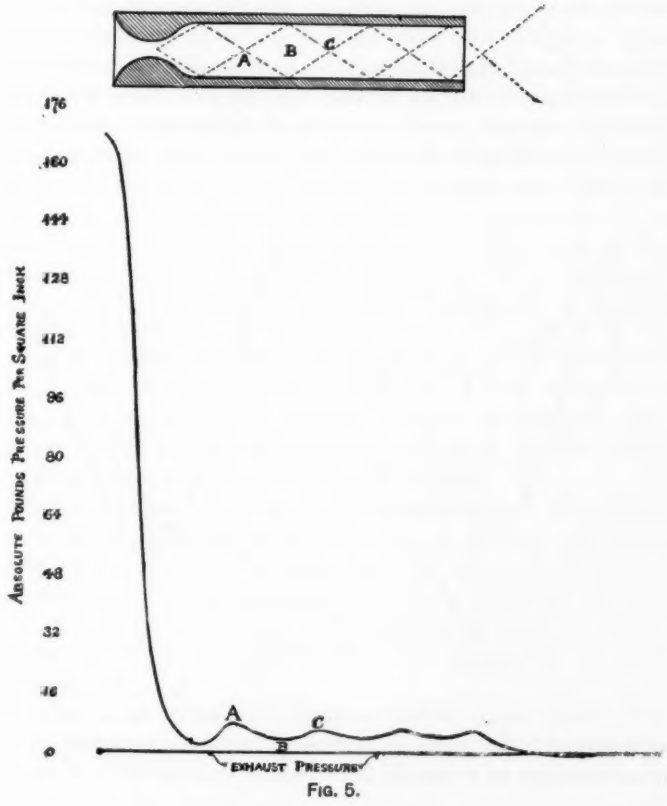


Fig. 5.

This feature is, to a certain extent, taken advantage of in a de Laval turbine designed for running non-condensing. The nozzle is slightly over-compounded so that the wheel may revolve in a partial vacuum. Some gain in economy is the result, by reason of the wheel revolving in a less dense medium.

Fig. 5 shows rather a curiosity. This form of nozzle was suggested as being as suitable as any that might have carefully constructed curved walls, and that the steam itself would take the correct passage and give the same results, so long as the correct ratio of throat area and outlet area were maintained. It will be observed how the pressure line forms waves, which exactly correspond with some lines shown in the nozzle, which appears as though the steam particles fall very near to the exhaust pressure immediately on leaving the throat. They strike the walls and rebound, meeting together at the point *A*, when they form a point of pressure, again striking the walls at *B*, meeting again at *C*, and so on.

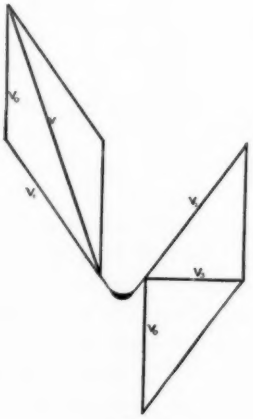


FIG. 6.

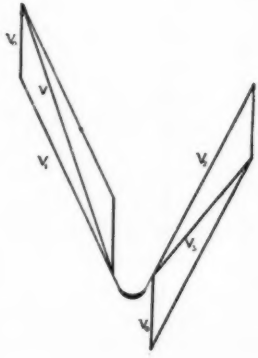


FIG. 7.

In the de Laval turbine the nozzles are set at an angle of 20 degrees with the plane of motion of the buckets, which is as acute an angle as is possible.

The action of the steam on the buckets may be shown by the diagram of parallelogram of velocities, Fig. 6, which shows an ideal condition which could seldom be obtained in practice.

V is the direction and velocity of the steam issuing from the nozzle.

Vo is the velocity and direction of the buckets.

Component V_1 is the relative angle and velocity with which the steam strikes the bucket.

V_2 is the *relative* direction and velocity of the steam leaving the buckets.

V_3 is therefore the *absolute* direction and velocity of the steam leaving the buckets.

It will be observed here that V_3 is a horizontal line, so that the combination is one of maximum efficiency, the only losses being due to the angularity of the nozzle.

By reason of the tremendous velocities of steam, a diagram similar to Fig. 7 is what is generally obtained in practice. It will be noted that the angle of the bucket at the entrance corresponds with that of the component V_1. It is usual to have the angle of outlet making an angle with the plane of motion equal to that of the inlet with the same plane, thus taking away practically all end thrust.

These turbines, especially the larger sizes, are equipped with several nozzles, some of which are provided with independent stop cocks, such that the number of nozzles in operation may be adjusted to suit the condition of running in order to obtain the most suitable steam pressure in the throats.

These turbines are essentially of very high speed. The smaller sizes run about 30,000 revolutions per minute, and are geared down to about 3,000; the larger sizes about 10,000 revolutions per minute. The peripheral speed of the wheel is usually from 600 to 1,200 feet per second. The reduction of speed is accomplished by means of a pair of helical spur gears with the angle of helix 45 degrees.

These gears form by far the biggest part of the whole outfit. The remaining portions of these turbines have no remarkable features. The regulation is effected by means of a fly-ball gov-

ernor, which is on the slower running shaft and wire-draws the steam at the admission.

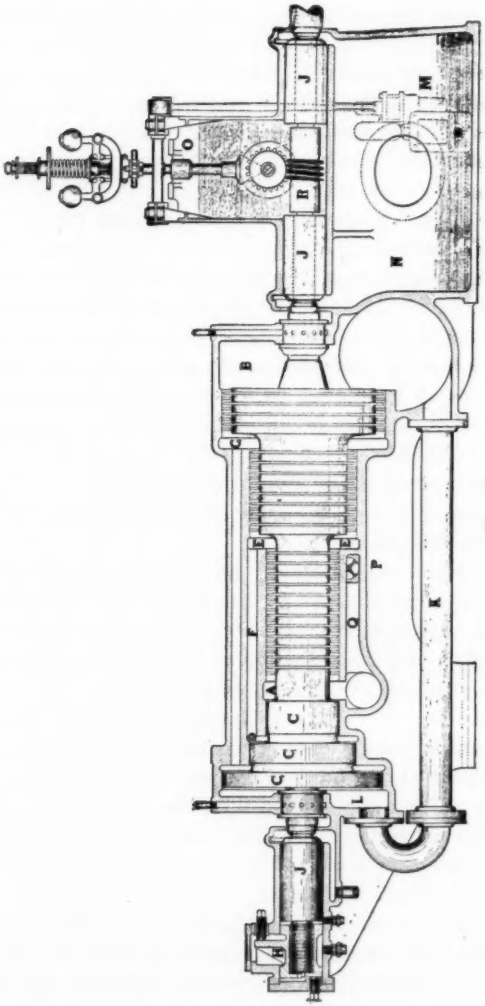


Fig. 8.

Some tests of a 10-H.P. turbine were communicated to the A. S. M. E. in 1895, in which the turbine described had four nozzles of .138 diameter and one of .157 diameter of throat. The nozzles were two inches long from throat to outlet.

The speed of the turbine was 23,771 revolutions per minute reduced by gearing to 2,400, the economy full load, non-condensing was 47.8 pounds per B.H.P. This economy is by no means bad when the small power of the outfit is considered.

In December, 1899, some tests were made in France under the following conditions: 192 pounds boiler pressure, with 69 degrees Fahrenheit of superheat; mean H.P., 307.8; revolutions per minute, 772. The consumption of steam was 13.92 pounds per effective H.P.

The first Parsons' steam turbine and generator was built in 1884. It developed 10 H.P. at 18,000 revolutions per minute. It ran for several years in Gateshead, on Tyne, England, supplying current for the manufacture of incandescent lamps. It is now in the South Kensington Museum. It consisted of two groups of 15 turbines each, the steam entering between them and passing in opposite directions through each group.

Fig. 8 is a general longitudinal section through a Westinghouse-Parsons Steam Turbine. The steam enters at the governor valve and arrives at the chamber *A* and passes out to the right through the turbine blades, eventually arriving at the exhaust chamber *B*. The blades are as shown in Fig. 15, the steam passing first a set of stationary blades and impinging on the moving blades, driving them around, and so on. The areas of the passages increase progressively in volume, corresponding with the expansion of the steam. They will, however, be described more fully later. On the left of the steam inlet are shown revolving balance pistons *C*, *C* and *C*, one corresponding to each of the cylinders in the turbine, which according to size may be 1, 2, 3 or 4 in number. The steam at *A* presses against the turbine and goes through doing work. It also presses in the reverse direction, but cannot pass the piston *C*, but at the same time the pressure, so far as the steam at *A* is concerned, is equal and opposite, so that the shaft is not subjected to any end thrust.

The pressure D is equal to that at E by reason of the balance port F, so similarly, so far as the steam pressure at E is concerned, there is no end thrust. This same fact also applies to G.

The areas of the balance pistons are so arranged that no matter what the load may be, or what the steam pressure or exhaust pressure may be, the correct balance is preserved and the shaft has no end thrust whatsoever.

At H is shown a thrust bearing which, however, has no thrust to take care of, but serves to maintain the correct adjustment of the balance pistons.

The thrust bearing is in halves, the lower half capable of adjustment in one direction, the upper one in the reverse.

The balance pistons never come in mechanical contact with the cylinder, and consequently there is no friction. The thrust bearing has ample surface, and besides is subjected to forced lubrication and does not wear. The adjustments once made always remain good.

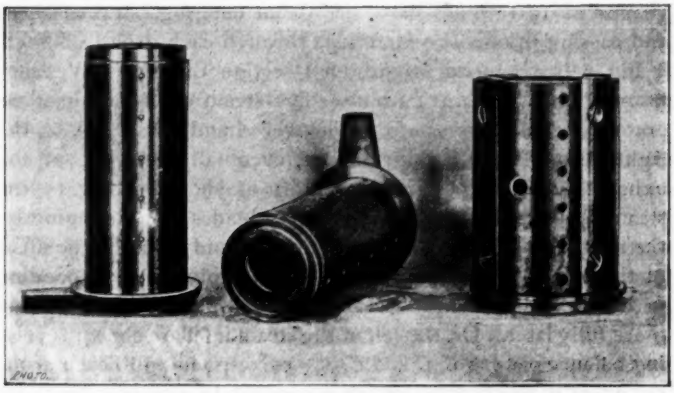


FIG. 9.

There is obviously some leakage past the pistons, but it is found to be very small. Centrifugal force seems to have something to do with keeping down this leakage. The particles endeavoring to escape have to pass radially inwards in going

through the small clearance. It is supposed, then, that the rapidly revolving pistons have the effect of throwing outwards the particles with which they come in contact by reason of skin friction, so that the particles being slung outwards tend to oppose the escape of the particles inwards.

This theory, however, is somewhat imaginary, but in view of the economy obtained the leakage cannot be very great.

At *K* is a pipe connecting the back of the balance pistons at *L* with the exhaust chamber (see Fig. 8) to insure the pressure at this point being exactly the same as that of the exhaust.

At *J* are shown the bearings. They are also shown separately on Fig. 9. They are unique in construction. The bearing proper is a gun-metal sleeve, which is prevented from turning by a loose fitting dowel. Outside of this are three concentric tubes having a small clearance between them. This clearance fills up with oil and permits a vibration of the inner shell, at the same time restraining same. The shaft, therefore, revolves about its axis of gravity instead of the geometric axis, as would be the case were the bearing of everyday construction. The journal is thus permitted to run slightly eccentric, according as the shaft may be out of balance. This form of bearing in a very remarkable manner performs the function of de Laval's slender flexible shaft. But in this case the shaft is built as rigidly as possible, so is not liable to crystallization which would result in eventual rupture.

The bearings have ample surface, are continuously lubricated under pressure, and it has been found in practice that they do not wear. As may be seen in Fig. 9, the bearings are surrounded by an outer cast-iron sleeve, in which are fitted keys which may be shimmed up and permit any adjustment of the position of the shaft relative to the cylinder.

At *R*, Fig. 8, is shown a flexible coupling by means of which the power of the turbine is transmitted. In small sizes the two shafts have a square cut on the ends, the coupling itself somewhat loosely fitting over these. In larger sizes it is generally a modification of this arrangement.

The governor gear and oil pumps generally receive their mo-

tion by means of a worm wheel gearing into a worm cut on the outside of the coupling.

At *N* is an oil reservoir into which drains all the oil from the bearings. From there it runs into the pump, *M*, to be pumped up to the chamber, *O*, where it forms a static head which gives a continuous pressure of oil to the bearings. The pump is single acting, of the simplest possible construction that will not become deranged. The oil runs in by gravity, so that it is unlikely to fail to continue pumping.

A by-pass valve is provided, shown at *P*, which admits high-pressure steam by means of port *Q* to the steam space *E*. By opening this valve as much as 60 per cent. overload may be obtained, and in the case of turbines operating condensing, full load may be obtained should the condenser be at any time inoperative, due to any cause, and the turbine allowed to exhaust into the atmosphere. Naturally, the effect of opening the by-pass valve is to reduce the economy to an extent that will be seen later when discussing economy.

The glands consist of packing rings set in grooves cut in the shaft. The rings press outward and remain stationary. Any form of frictionless packing necessarily leaks a little. In the case of the turbine exhausting into a vacuum, a little live steam is admitted between the rings by means of a small reducing valve, so that the leakage consists of a negligible quantity of live steam, instead of air which would impair the vacuum.

In the case of the turbine exhausting against anything above atmospheric pressure, a small ejector is provided, which drains the leakage steam from between the packing rings, and allows it to drain through a suitable drain pipe instead of escaping into the engine room.

In all engines the governor is an important consideration. A fly-ball type of governor is made use of, and has several features conducive to good regulation. The ball levers are swung on knife edges in lieu of pins. The governor works both ways, that is to say, the midposition of the levers is admitting a full head of steam to the turbine. A movement from this in either direction is tending to cut off the supply. This serves a useful

purpose in the event of a very excessive load coming on the turbine, such as a short circuit, which has the effect of bringing down the speed more than the percentage variation permitted by the adjustment of the spring, when the steam immediately becomes shut off. Again, in such an event as some of the governor-driving mechanism becoming broken and the governor balls slowing up independently of the turbine, the steam is shut off before any damage could take place.

The speed of the turbine may be varied within all the limits of the governor spring while the turbine is running. This is particularly useful in bringing alternators in synchronism and adjusting their differences of load when in multiple. This is accomplished by grasping the top knurled head, when by means of a ball bearing shown, the spring and tension nuts remain stationary. Any adjustment of the spring nuts may then be made, without in any way disturbing the running of the turbine other than making the change that may be desired.

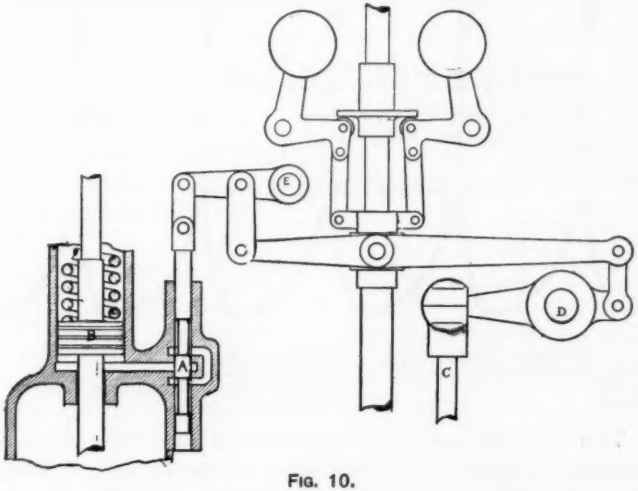


FIG. 10.

The arrangement of the governor levers is shown diagrammatically in Fig. 10. They are attached to a small relay valve, *A*,

which controls the steam below the piston, *B*, which is directly connected to the main admission valve. The levers receive reciprocating motion at *C* from an eccentric and use the governor clutch as a fulcrum, points *D* and *E* being fixed. Continuous reciprocating motion is thus given to the relay valve. This is in turn transmitted to the admission valve. The function of the governor is to vary the plane of oscillation of the relay valve, which causes the admission valve to remain open for a longer or shorter period, according to the position of the governor. The steam, therefore, is admitted to the turbine in puffs, which occur at constant intervals of time. The puffs are of either long or short duration, according to the load. At full load the puffs merge into an almost continuous blast. If we were to attach an indicator to the steam space *A*, Fig. 8, and pull the drum around by hand, we would produce a series of cards similar to Fig. 11.

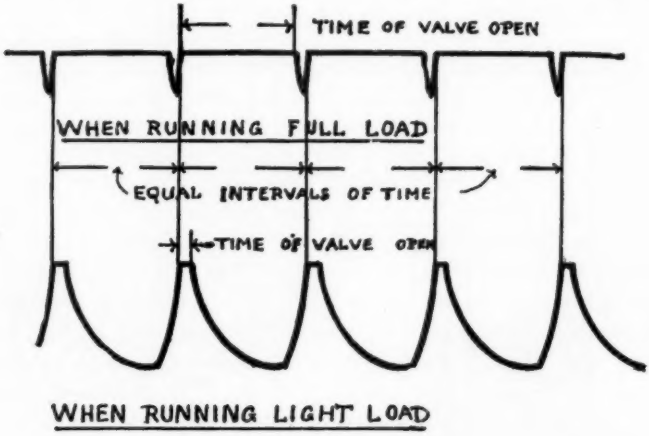


FIG. 11.

This does not mean that in the latter case there is a more complete expansion of steam than in the former; it simply means that high-pressure steam is made use of at all loads. The complete expansion of the steam is taken care of independently in the blades.

The advantages of this intermittance are three-fold. The turbine is at all times using boiler-pressure steam, no matter what the load may be. The admission valve is continuously in motion and consequently gets no opportunity to get stuck. The power to work the relay valve and overcome the inertia of the levers is transmitted through the governor clutch, hence the balls are moved in and out a very small amount at every oscillation of the levers, so that the governor levers in respect to their motion about their points of suspension are never at rest, and consequently when a change of load comes, the governor does not have to overcome the friction of rest, and is always ready to go to its new position.

These features are particularly valuable. So long as a piece of mechanism is continuously working we at least know it is in a condition to continue working and is not stuck.

There is absolutely no variation of angular velocity in the turbine, which is necessarily present in reciprocating engines, hence the value of turbines for running alternators in multiple. This can be realized when we know a 500-H.P. turbine will run 20 minutes after the throttle has been closed. This, of course, speaks well for the low friction, but is principally due to the tremendous fly-wheel effect of the shaft. All the power is transmitted rotatively—there are substantially no reciprocating parts and no vibrations, hence no costly foundations and no holding-down bolts are necessary.

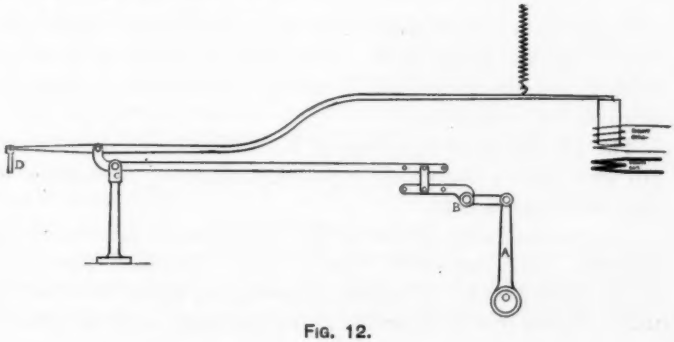


FIG. 12.

Mr. Parsons made very successful use of an electrical governor which was attached to a relay valve working in exactly the same manner as just described. The arrangement of the levers is shown in Fig. 12. Reciprocating motion was given at *A*, points *B* and *C* being fixed. On the extreme right is hung, by means of a spring, a core working in a solenoid. When in operation, the relay valve *D* oscillates continuously and the core moves a very small amount by reason of its mass. At the same time it is ready to respond to any change of magnetic pull. One great feature of this governor is that the solenoids may be compounded so as to give constant E.M.F. at the terminals of the generator, the turbine running faster at full load than at light load, to make up for copper losses in the armature. The governor may be further over-compounded to give any percentage rise, just the same as an over-compounded generator.

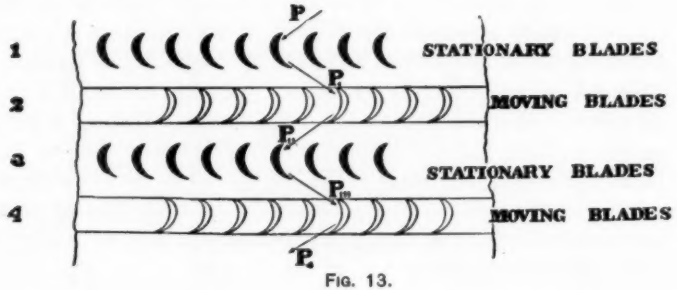


FIG. 13.

In alternating-current work the series coil is obviously separated from the shunt coil. This latter is in shunt with the exciter, and the series coil is usually placed above, having a separate laminated core.

The adjustment of variations of E. M. F. between no load and full load may be conveniently made by changing the amount of iron in the series core.

The essential parts of the turbine are of course the blades and buckets. They are made of hard drawn material. They vary in size from $\frac{1}{2}$ inch to 7 inches, according to where they may be used. Every row of these blades has passages of increased area,

corresponding with the volume of the steam. This increase of volume is obtained by increasing the heights of the blades, and when these have reached the desired limit, the diameter of the turbine is increased and the steam permitted a higher velocity that enables the blades to recommence another progression.

Considering one barrel of the turbine, the fall of pressure, or to be more exact, the coefficients of expansion, are the same for every row.

Referring to diagram, Fig. 13, the steam at pressure P in expanding through row 1 to pressure P_1 converts its energy into velocity and impinges upon the moving blades, row 2. The steam then performs a second expansion in expanding through row 2, again converting its energy into velocity, but this time the energy of the efflux is to react upon the blades from which the steam issues. The same cycle is repeated in row 3 and row 4, and so on until exhaust pressure is reached. The moving blades therefore receive motion from two causes, the one due to the impact of steam striking them, the other due to the reaction of the steam leaving them, and in this respect is this turbine a combination of Bianca's wheel and Hero's engine.

Many people suppose that these blades wear under the action of steam. Experience shows that they do not. In the case, however, of a nozzle, such as has already been described, in combination with the blades, the result is very different, by reason of the tremendous velocity of the steam. The wear even then is not much when superheated steam is made use of, but with any entrained water the wear is quite rapid. In the Parsons turbine the velocities of steam never exceed 500 to 600 feet per second, and for the most part are considerably less than this.

The blades are secured by calking in the manner shown by the samples. Experiments show that the pull necessary to pull them out is as much as the elastic limit of the material of the blades themselves. The strain to which they are subjected in practice is about $\frac{1}{40}$ of this amount.

It may be observed in some of the smallest samples that you have before you that a blade has been pulled out in order to test the resistance. The pounds pull have been marked on the side,

and are of figures ranging from 300 pounds to 400 pounds. In every case the blade stretched considerably before it came out.

Danger of the blades colliding sideways is very remote. The smallest blades have $\frac{1}{8}$ inch clearance sideways and the largest as much as $\frac{1}{2}$ inch. These dimensions are far beyond the limits of lateral motion permitted by the balance pistons. Of course accidents *do* happen to the blades, but are generally attributable to carelessness, such as the machine having been taken apart and in handling, some of the blades damaged, the machine being again assembled without having the damage repaired. The result of this, however, is less serious than would be expected. At the most, two or three rows are ripped out. The blades are very tough, and the first broken blades close up the passage in the succeeding guide blades and prevent the broken pieces passing and causing more damage.

In the event of such an accident, the damaged blades may be removed and the machine put into service when full power can be developed, but of course at a somewhat less efficiency, according to the number of rows missing. The blades may be permanently repaired in a very short time by chipping out the grooves and inserting new blades. This work can be done wherever the machine may be in service, as no special machine work is necessary. Such accidents, however, are among the improbabilities.

It may be interesting to record the actual pressure exerted on individual blades in a turbine. Take, for example, one of 300 kilowatt capacity, to which special reference will be made. There are altogether 31,073 blades in the turbine, of which 16,095 are moving blades. The pressure that each of them exerts in revolving the shaft varies from .89 to 1.04 ounces.

The steam inlet is always provided with a steam strainer, which is intended to prevent foreign substances from getting into the turbine by means of the steam pipe. Generally such things as nuts, bolts, monkey-wrenches, etc., as have occasionally been known to come through a steam pipe, cause practically no damage because they cannot pass the first row of guide blades. The greatest inconvenience of this nature are small pieces of

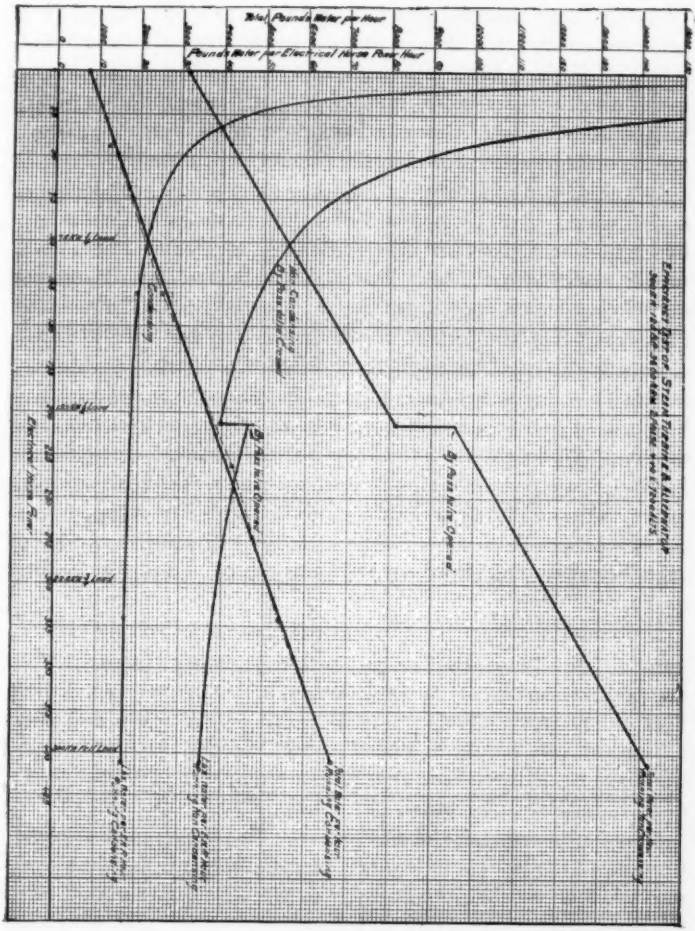


FIG. 14.

gasket choking up the guide-blade passages, which appreciably brings down the power.

As has been already stated, a jet of steam issuing through a properly constructed orifice has as much energy as the same steam performing high ratios of expansion behind a piston. In both cases the work to be theoretically abstracted from a given weight is the same. However, there are some practical reasons for expecting better results in the case of the turbine.

In the design of a three or four-stage compound, condensing, reciprocating engine, it is found that there is no gain in economy by expanding the steam in the low-pressure cylinder beyond a terminal pressure of about 5 or 6 pounds absolute. To do so means very much increasing the volume of the L.P. cylinder, thus increasing the friction of the engine and the weight of reciprocating parts. Moreover, the temperature of saturated steam, as these low pressures are reached, falls off much more rapidly; hence there are greater losses, due to condensation and re-evaporation, than would be gained by a more complete expansion. In the steam turbine no such limits exist. The extra volume of the L.P. end does not add to the friction. The temperature conditions from end to end remain always the same, and hence such losses as condensation and re-evaporation are not in evidence.

Turbines are constructed to utilize the energy of the steam down to the utmost limits. A condensing steam turbine, when in operation, affords a striking example of the conversion of heat into energy. The temperature of the walls of the cylinder at the high-pressure end, about 365 degrees Fahrenheit, falls in the distance of three or four feet to a temperature of about 126 degrees at the low-pressure end.

The diagram, Fig. 14, shows some economy curves developed from tests made on one of the 300-kilowatt turbines now in operation at the Westinghouse Air Brake Co.'s works. The results may be summarized as follows:

Full load, . . . 16.4 pounds, steam per E.H.P. per hour.
Three-quarter load, 17 pounds, steam per E.H.P. per hour.
Half load, . . . 18.2 pounds, steam per E.H.P. per hour.
One-quarter load, 22 pounds, steam per E.H.P. per hour.

Running light, 750 pounds, per hour.

Vacuum, 26 to 27 inches.

Boiler pressure, 125 pounds per square inch.

Revolutions per minute, 3,600.

The consumption of 16.4 pounds at full load is in itself remarkable, but such results as at the light loads have never been approached before. It may be said that the consumption at one-half load is only 10 to 12 per cent. greater than at full load.

It must not be lost sight of that these results are per electrical horsepower. It is usually the custom of engine builders to publish their results per *indicated horsepower*, which means very little to the power user. He is chiefly interested in the economy of steam per unit of power, he gets out of his power plant, not the steam per unit of power he has to put into it.

To make a comparison with a reciprocating engine, and assume the efficiency of transmission from the steam cylinders to the switch board to be about 85 per cent., which is about the very highest attainable, would bring the full load-water rate on the turbine just described to 14 pounds per indicated H.P. The tests were made under ordinary conditions so far as dryness of steam is concerned, the boilers being some distance away, and no allowance made for wetness of steam.

On the curves are shown a set of lines showing the efficiency when running non-condensing. These results are somewhat inferior by reason of this particular turbine being designed essentially for condensing. Nevertheless, the results are not so bad as to preclude it being operated under these conditions, should at any time the condenser be out of order.

A turbine designed for running non-condensing gives proportionately as good results as the condensing curves shown on the diagram.

By this set of curves may be observed the function of the by-pass valve, how, when running non-condensing, the by-pass valve remained closed until about half load was reached. Upon being opened the efficiency fell off, as shown, and continued to improve from there on as the load increased. The over-load capacity of the engine is obviously more flexible than that of most engines.

Superheating may be made use of with considerable gain in economy and without the usual difficulties. There are no internal rubbing surfaces and no packing glands to become injured by the high temperature. Sixty degrees to seventy degrees of superheat improves the economy by some 20 per cent.

In this connection Prof. Thurston has lately recorded some experiments with a de Laval turbine. For every 3 degrees Fahrenheit of superheat 1 per cent. of gain in economy was attained. With 37 degrees of superheat the capacity of the turbine was doubled. This gain he attributes almost entirely to the reduction of skin friction.

The practical efficiency of a turbine-power plant may be gathered by some tests made by the Westinghouse Air Brake Co. After the plant had been installed some nine months the whole plant was shut down, and the steam engines which had been previously doing the work, were connected up again, put in service, and were kept running a week, during which time careful measurements were taken of fuel and water. After this the turbine plant was again put in operation and similar measurements made with the electrical transmission. The saving in coal averaged 35.7 per cent. during the day and 36.4 per cent. during the night in favor of the turbines. The saving in feed water averaged 29.8 per cent. during the day and 41.4 per cent. during the night. In round numbers, this means a saving of 40,000 pounds of coal in 24 hours.

The gain is in a great measure due to the economy of the turbines, but also to some extent to the elimination of the condensation in long lengths of steam pipe, and to the advantages of electrical transmission.

Fig. 15 shows the complete revolving part of a 3,000-H.P. turbine. Its weight is 28,000 pounds; length over all, 19 feet 8 inches, and 12 feet 3 inches between bearings; the largest diameter, 6 feet.

The turbine, of which this forms a part, is being set up in the power house of the Hartford Electric Light Company. It is direct connected to a 1,500-kilowatt generator; the total outfit having the following dimensions: 33 feet 3 inches long and 8

FIG. 15.

feet 9 inches wide; 175,000 pounds, total weight, including generator. This is the largest steam turbine in one integral part ever built.

As there are no rubbing surfaces in the turbine, no internal lubrication is necessary. This enables surface condensers to be employed and the condensed water used for boiler feed without fear of getting grease into the boilers.

The turbine is entirely automatic in all its functions, and requires remarkably little attention. The only real working part is the spindle revolving in its bearings. These bearings are found to wear but little, if at all, so the cost of repairs and renewals is very small.

In 1897, the Newcastle & District Electric Lighting Co. published their costs in this regard. The power house contained eleven turbines of 75 to 150 kilowatt each. The cost for repairs and renewals amounted to $\frac{26}{100}$ cent per kilowott per annum, and included all repairs to boilers, turbines, condensers, pumps, generators, cables, fittings, etc.

By reason of the turbine making use of the last available expansion of the steam, there is considerable advantage in employing the highest vacuum. For instance, considering the 300-kilowatt turbines described, and assuming the steam consumption with 27 inches vacuum to be 16.35 pounds per electrical horsepower hour, it may be reasoned upon a thermodynamic basis that with the same machine designed for 25 inches vacuum the consumption would be 18 pounds per electrical horsepower hour.

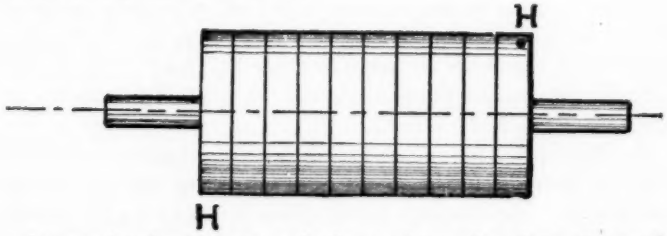
On the other hand, by designing the same turbine to suit an exhaust pressure of $\frac{1}{30}$ of an atmosphere, or say 29 inches vacuum, the consumption would come down to 14.12 pounds per electrical horsepower hour.

The applications of steam turbines are perhaps not so universal as ordinary steam engines. They are pre-eminently suitable for driving electrical machinery, particularly alternating-current dynamos. Some difficulties are, however, experienced with the commutation of continuous-current generators of fairly large powers.

There is nothing remarkable in the design of generators for this purpose, except that modification necessitated by the high speed. For this reason they are remarkable for their small weight and dimensions and the absence of crowded pole pieces.

Builders of electrical machinery have for some years been working in the direction of reducing speeds from the old belt-driven rigs to admit of direct connection to slow-going reciprocating engines. The condition for steam turbines is, however, a step in the reverse direction. Turbines have been used with good success in England for driving fans and blowers.

Although the type of bearing employed is capable of successfully dealing with about any reasonable error in balance, at the same time it is very essential that the revolving parts be very accurately balanced, in order that the collector rings and commutators may run true, and that the clearance between the tips of blades and walls of the turbine cylinder may be maintained as fine as possible, so that balancing forms quite an important stage of the construction and has many interesting features. The usual method of balancing, which consists of rolling the piece on some ways and thus locating the heavy side, is sufficiently accurate for ordinary slow-speed work, but no degree of real accuracy can be attained.



Attempting to balance a body, such as the above, by such methods, might result in a heavy spot at two opposite sides and two opposite ends, as at *H* and *H*, which would be anything but a condition of good running balance. It is, therefore, found desirable to split this up into comparatively narrow rings and balance each separately, when the above error would become negligible. For balancing such rings, The Westinghouse Ma-

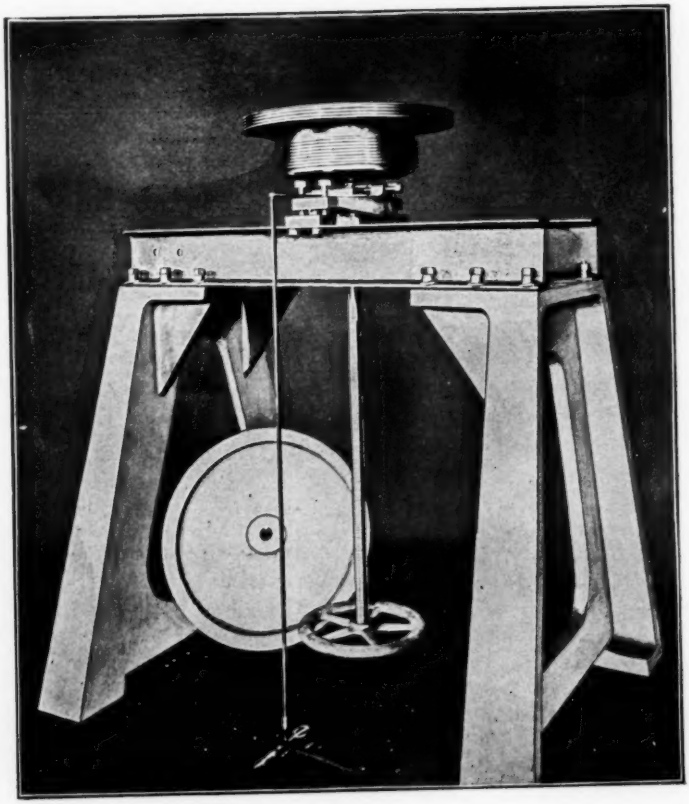


FIG. 17.

chine Co. have devised a machine which performs the work with remarkable accuracy. It is shown in Fig. 17, which shows a ring in place on the turntable. The turntable is pivoted on a beam which is in turn hung on two knife edges. Below the turntable is rigidly attached an adjustable counterweight. The turntable of course is free to turn independently of all this. Means are provided to slide the whole turntable and counterweight in the beam and in a direction at right angles to the line of the knife edges.

The counterweight is adjusted to bring the combined center of gravity in a plane close to the knife edges. Then by sliding the mass in the beam the table may be made to rest horizontally. Then by giving the turntable ½ revolution the table will fall over by twice the amount it is out of balance. Readings are taken in two opposite directions, and the exact location and amount of the error may be immediately figured.

Balancing by this method may be done very rapidly and with surprising accuracy. A ring weighing 6,000 pounds has been balanced within two ounces, and rings weighing 200 or 300 pounds within one-eighth of an ounce.

In the case, however, of the revolving parts of electric generators the final winding, etc., is liable to throw it out of balance, and then there is no alternative but to balance it in its entirety. The shape is generally of the nature of a long cylinder with a journal at both ends. The only way, then, to do this balancing is to deliberately mount it on bearings which are preferably set on springs and running it up to speed by belt or any available means. While running it is marked with a colored pencil at different points, which serve to indicate where to add weight.

A small body revolving at 5,000 or more revolutions per minute—the light side is always the side that comes outward, so that weight should be added just where the marks come. In some cases the marks are opposite at each end, when weight needs to be added on one side at one end and on the other side at the other end.

These facts show that when the high speeds are reached the body ceases to revolve on the geometric axis and takes the axis of gravity.

On its way up to speed there is generally some point at which there is considerable vibration. This is termed the critical speed, and seems to come at the time the body is changing its axis of revolution. These critical speeds become lower as the bodies are heavier and of greater radius. In the cases of heavier and bigger bodies, which also would have a lower rotative speed, the marks do not come just on the light side. They may come sometimes as much as 90 degrees ahead of the light side. The exact angle can only be found by experiment, and at best this is only a cut-and-try method. With experience, however, work may be put in very accurate balance.

The application lately of steam turbines to marine propulsion is well known. Some particulars of the vessels equipped may be interesting.

The first vessel, named the *Turbinia*, was built with a view of exploring the possibilities of turbines for this purpose. It was therefore built as small as possible, and at the same time not so small as to preclude the attainment of high speed should the experiments turn out a success. The dimensions selected therefore were 100 feet long, 9 feet beam, 3 feet draught and 44 tons displacement. It will be noted that the ratio of beam to length is unusually small—$\frac{9}{100}$, while $\frac{10}{100}$ or $\frac{11}{100}$ is the more usual practice for this class of boat.

To begin with, the boat was fitted with one single turbine and propeller. The result was disappointing, the chief trouble being due to cavitations in the propeller, resulting in excessive slip. This was verified by experiments in a tank of water subjected to vacuum. The appearance of the action of the propeller in the water was observed by looking through a slot in a disc which was made to revolve in synchronism with the propeller under observation.

It was then considered necessary to make several changes. New engines were built, in three sections, the steam expanding through them in series, each section driving an independent shaft and each shaft three propellers. Very soon 32¾ knots were attained, and eventually 34½ knots, at the naval review at Spithead in 1897. About 2,300 I.H.P. were developed. The

boiler, a Yarrow type with small tubes, had 1,100 square feet heating surface and an evaporation of about 28 pounds of water per square foot of heating surface at 34½ knots speed. About 600 I.H.P. were developed per ton of machinery and 50 I.H.P. per ton of total weight of vessel in full equipment. These successes resulted in a contract with the British Admiralty for a torpedo-boat destroyer named the *Viper*. The dimensions were the same as the 30-knot destroyers of her class, 210 feet long, 21 feet beam, and 350 tons displacement. The engines consisted of two independent sets, each consisting of one high-pressure turbine driving a shaft, and one low-pressure turbine driving its shaft. On the same shaft as the low-pressure was permanently connected a small turbine for reversing purposes. When running ahead the reversing turbine was in connection with the condenser, so that the frictional losses due to this turbine running idle were very small. The same fact applies to the go-ahead turbines when running astern.

There were, therefore, four propeller shafts, each fitted with two propellers; the one ahead having a slightly lesser pitch than the after ones.

The Yarrow-type boilers have 15,000 square feet heating surface; grate surface, 272 square feet; condensers have 8,000 square feet surface. The speed attained was 35 knots to begin with, and later 36.858 knots were reached.

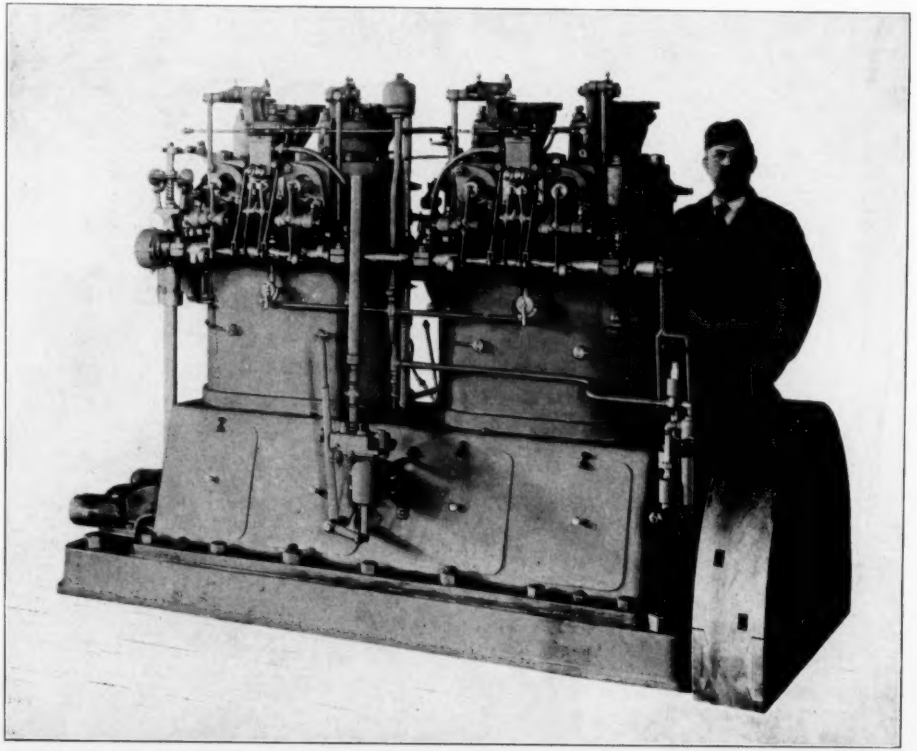
It is generally conceded by engineers that but little more may be anticipated in the development of the reciprocating engine. Any improvement that we can imagine would not very materially improve its efficiency as a heat engine. On the other hand, the turbine is capable of development in many ways, particularly in the use of superheated steam, to a degree hitherto prohibitive, so that the day may not be very far distant when the turbine will replace the reciprocating steam engine for most purposes.

In conclusion, I must express my thanks for your kind attention and my indebtedness to the Westinghouse Machine Company, for their permission to read this paper and for the use of the various drawings and photographs, etc., that we have had before us.

GASOLINE ENGINES FOR HOLLAND SUBMARINE TORPEDO VESSELS NOS. 3 TO 8.

COMMUNICATED BY JOHN SALTAR, JR., PRESIDENT OF THE OTTO GAS ENGINE WORKS.

The history of steam power, dating from the reaction experiment of Hero (about 120 B. C.) and extending through the centuries to the middle of the eighteenth, when the steam piston and cylinder had come into use to a slight extent for pumping engines, is interesting and shows a gradual development of much theory and little practice. Although the cylinder and piston were developed before his time, yet all the world concedes to James Watt the title of Father of the Modern Steam Engine, and the honor which its advantages have bestowed upon mankind. In the same manner the history of gas power, beginning with some theorizing upon the use of gunpowder by Hautefeuille in 1678, extends over nearly two centuries to the time of Dr. N A. Otto, without accomplishing any more really practical success than had been obtained with the steam engine before Watt's day. The inventive genius, practical good sense and patient, unwaivering persistency of this man created the gas engine of to-day, and to him is generally conceded the honor of being the Father of the Modern Gas Engine. A few interested critics, almost exclusively confined to this country, alone take frequent occasion to belittle his fame, and upon the following ground: A few years before his invention had developed a Frenchman, by the name of Beau de Rochas, had advanced many impractical ideas with regard to the gas engine, and with them the new well known "four-cycle" movement. This latter seems to have been about the only practicable idea which he suggested, but, so far as history records, he never attempted to apply to practice any of his theories.



GASOLINE ENGINES FOR HOLLAND SUBMARINE TORPEDO VESSELS, Nos. 3 TO 8.

The earliest effort of Otto was the production of the free piston or "atmospheric" engine which was the first practical success and of which thousands were built, many running to this day, and the economy of which has not yet been exceeded. But it was bulky and could not be reasonably built in sizes larger than four horsepower, and Otto, being dissatisfied with it on that account, turned his efforts in other directions and re-invented the famous "four-cycle", placed it in practical form and brought out the modern gas engine essentially as we have it to-day.

Beau de Rochas and his theories had received no attention and were lost among dusty and forgotten records until after Otto's triumphant success. This success itself set searchers to work, and Beau de Rochas and his theories have lived as a result.

The relation of Beau de Rochas to Dr. N. A. Otto is much the same as that of Lief Erickson to Columbus. Columbus discovered America, that is, he uncovered it, and in uncovering America to the world he uncovered or discovered Lief Erickson, who had previously landed on this continent, and made him famous. In exactly the same manner Dr. Otto invented or discovered and thus uncovered the Otto four-cycle, and in doing so he uncovered and made famous Beau de Rochas. There has been so much petty and jealous discussion of this point that we think it but fair to make these facts known, and let honor be awarded where it is due. No less in authority than Mr. Dugald Clerk, who was a defeated legal and commercial competitor of Dr. Otto, gives full credit to the Doctor in his famous authoritative Treatise on the Gas Engine.

It is but twenty-five years since the first Otto cycle gas engine was built by the Otto Works at Cologne, Germany. Two years previously this company had sent to the United States Messrs. Schleicher Bros., to exhibit their atmospheric engine at the Philadelphia Centennial Exposition in 1876, and to manufacture and introduce it in the United States. It was not until 1878 that the Otto Gas Engine Works of Philadelphia, then known as Messrs. Schleicher, Schumm & Co., built and sold the first modern gas engine in this country. This engine was purchased by the United States Government for use in the arsenal at Water-

town, Mass., and was afterwards transferred to the United States Arsenal at Indianapolis, where it is running to this day. Many engines have since been purchased by our Government from the same company for every kind of service on land, and now at the beginning of this new century the United States Navy demands and the Otto Gas Engine Works designs and builds another special type of gas engine, suitable for marine and submarine work. The Army gas engine of 1878 was 4 indicated horsepower; the Navy demands an engine in 1901 which will develop 160 actual horsepower at 360 revolutions per minute, and are supplied with one which will yield a maximum of 200 horsepower at that speed.

In adopting the Otto engine for his submarine boats Mr. Holland has made an important advance. The steam engine with its boiler is excessively hot, dangerous, dirty and inconvenient. It requires from six to ten times the weight of fuel to be carried for the same amount of power. It is troublesome on account of the rapid shifting of the ballast as the fuel is burned, and the range of action is limited. The fact that the gas engine lacks these disadvantages makes its place secure in submarine work and opens a new chapter of the history of the displacement of the steam engine by the gas engine.

DESCRIPTION OF ENGINES.

The engines now being built for the seven Holland submarine torpedo boats for the United States Navy are of the Otto cycle type, in which the successive operations take place as follows:

1. *Suction Stroke.*—During the first suction stroke of the piston, with the air and fuel valves open, a cylinder full of mixture of air and fuel (in this case gasoline) is drawn into the cylinder.

2. *Compression Stroke.*—On the return stroke, with all the valves closed, the mixture is compressed, and at the end of the stroke ignited by means of an electric spark.

3. *Expansion Stroke.*—During the following forward stroke the combustion and expansion of the compressed mixtures drives the pistons and transmits the power to the crank shaft.

4. *Exhaust Stroke.*—The products of combustion are expelled

during the return stroke of the piston, the exhaust valve being opened at the beginning of the stroke.

The discharge of the burnt gases completes the cycle, and the operations are repeated over and over again when the engine is working at full power, each cylinder yielding one impulse, or "expansion stroke" every alternate revolution of the crank-shaft.

The engines under consideration in this article are of the marine type, inverted, with crank shaft below. Four cylinders, single acting, of equal size, are mounted in tandem upon one frame, which is bolted to the main engine bed. The cylinders are water jacketed, each pair having one common jacket cast in one piece with the two cylinders. The pistons are of the trunk pattern, with long guiding surfaces serving as crossheads, the connecting rods being attached directly to the pistons. The crank shaft is supported by the three main bearings of the engine bed, and the four cranks and reciprocating parts are so disposed as to balance as perfectly as possible.

The inlet and exhaust valves are located in the cylinder heads. All valves are of the poppet type, and the cylinder heads and exhaust valve casings are water jacketed throughout. All valves are operated by levers actuated by cams which are mounted upon sleeves keyed to the cam shaft running alongside and near the top of the four cylinders on the starboard side of the engine. The cam shaft makes one-half the number of revolutions of the crank shaft, and the motion is transmitted from the latter by two pairs of skew gears, through a vertical intermediate shaft.

The electric igniters are actuated by eccentrics from the cam shaft. They are of the patent of the makers, and both the movable and fixed electrodes are fitted with platinum points.

The distribution of the cranks, the setting of the cams operating the valves, and the timing of the igniters are arranged so as to give an impulse in one of the cylinders during each stroke of the engine, working at full load. In other words, the operations in the four cylinders alternate, so that while one is on the expansion stroke, the other three are on the suction, compression and exhaust strokes respectively.

The governor is of the centrifugal ball type, and controls the

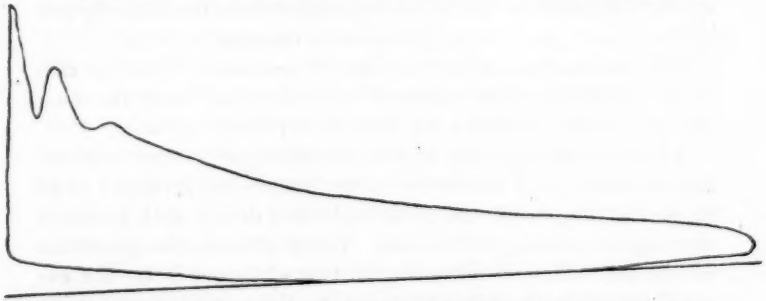
speed of the engine by entirely cutting off or admitting charges of fuel to any or all of the cylinders, according to the load carried by the engine. The speed can be varied, while the engine is running, by means of a hand lever, allowing a range of speed from 200 to 360 revolutions per minute.

The main brasses, connecting-rod brasses, and all other bearings are of phosphor-bronze, and the bearing surfaces are liberally proportioned to conform to the speeds and pressures developed in the engine.

The lubrication of the pistons, main and connecting-rod brasses is supplied from the two oil reservoirs, one fastened to each pair of cylinders on the port side of the engine, each reservoir having two compartments, one for cylinder oil and one for bearing oil. The oil reservoirs are provided with sight feeds and valves for adjusting the flow of oil, one for each bearing.

The engine is started by means of a convenient starter which consists of a small hand pump bolted to the frame on the starboard side, a small gasoline reservoir with valves for mixing air and fuel attached to the top of the hand-pump cylinder, and suitable valves for admitting a charge of mixture from the hand pump to each cylinder.

One man can easily start the engine by turning the fly wheel so that the cranks are in proper position for starting, pumping a few strokes of mixture into each cylinder and snapping off the



Area of diagram, square inches	2.225	Scale of spring, per square inch, per inch rise, pounds	200
Length of diagram, inches	4.5		
Mean pressure per square inch, pounds	98.4	This card was taken from one of the cylinders of engine No. 8,891, for U. S. Submarine Torpedo Boat *Adder*.	
I.H.P. at full load	55.3		

leading igniter by hand. The explosion resulting from this operation is sufficient to turn the engine over until the following cylinders reach the expansion stroke, and the engine starts off instantly.

We are able to present herewith a half-tone print of one of these engines, and also a cut of an indicator card.

SUPPLEMENT BY LIEUTENANT COMMANDER STACY POTTS, U. S. N.

The specifications for the main engines for the seven submarine torpedo boat vessels require them to be of the Otto gasoline type, with four cylinders each, single acting, balance to prevent excessive vibration; the horsepower to be 160 at 360 revolutions per minute, consuming about one pint of gasoline per horsepower hour; the gasoline tank to have a capacity of 850 gallons; speed of ship with main engines at full power to be eight (8) knots per hour.

On December 20th, 1900, the first of these gas engines was tried at the works of the builders. The engine was started at 1 P. M. and ran continuously until 5 P. M., the resistance being a Prony brake attachment on the rim of a water-cooled brake pulley with equivalent weights of 455 pounds on the end of a lever 5 feet 9¼ inches long. The engine made an average of 322 revolutions per minute, being counted at numerous intervals with watches and portable counters, and developed 160.4 horsepower.

The gasoline, of .74 specific gravity (Baumé scale), was drawn from a graduated tank with glass gage attachment and was used at the rate of .88 of a pint per brake horsepower.

As it was found that the required horsepower of 160 could be developed by running the engine at 320 revolutions instead of 360, as specified, it was agreed to by the representative of the Holland Torpedo Boat Company and by the contractors of the engines, and approved by the inspector, he having witnessed the same engine running 360 revolutions on one of the previous preliminary trials and developing over 190 horsepower.

Immediately after the four-hour trial, all the bearings were

examined and found to be perfectly cool, no water having been used on them at any one time.

The engine ran smooth, with little or no vibration, the only objectionable feature being the noise of the exhaust into the atmosphere and the heat radiated from the exhaust pipes, but this feature will be eliminated to a great extent when placed aboard the boats, by surrounding the exhaust pipes with circulating water, to prevent the radiating heat, and to exhaust beneath the surface of the water at the stern to obviate the noise.

Since the above trial two other sets of similar engines have been tried, each trial showing an improvement over its predecessor in the amount of gasoline used and the general running of the engine, which shows that advantage is taken from past experience, and continued improvement the order of the day.

ENGINES AND BOILERS OF THE *INCHDUNE* AND *INCHMARLO.*

[From "Engineering," January 18, 1901.]

The machinery of the vessels *Inchdune* and *Inchmarlo*, belonging to the Inch Line of steamers, which is owned by Messrs. Hamilton, Fraser and Co., of Liverpool, is of very great interest, not only from its construction, but also on account of the highly economical results which have been obtained by it. The engines, constructed at the Central Marine Engine Works, West Hartlepool, are a modification of the quadruple-expansion five-crank type, advocated by the late Mr. Mudd, and fitted to the S. S. *Inchmona*. The alterations made in the design have been fully justified by the results obtained, both as regards actual working of the machinery and economy of fuel. The working pressure has been increased to 267 pounds per square inch, and the steam is superheated to a temperature approaching 500 degrees Fahrenheit. The general result is that on an extended trial from Hartlepool to Dover the coal consumption was at the unprecedentedly small rate of .97 pound per indicated horsepower. If we increase this to 1 pound, it works out to 15½ tons per day for a ship carrying 6,170 tons at 9½ knots, or to 13¼ tons at 9 knots. In other words, 1 ton is carried 1 nautical mile on an expenditure of about one-third of an ounce of coal. Taking coal at 15s. a ton, 1 ton of cargo is carried over 550 miles for an expenditure of 1d. for fuel.

There are five cylinders, two of them being low-pressure cylinders, the expansion being done in four stages. The diameters of the cylinders are respectively 17 inches, 24 inches, 34 inches, 42 inches and 42 inches, the stroke in every case being 42 inches. The high-pressure valve is of the piston type, all the others being ordinary flat valves. All the cylinders are fitted with liners, which permits of complete jacketing, with the exception of the

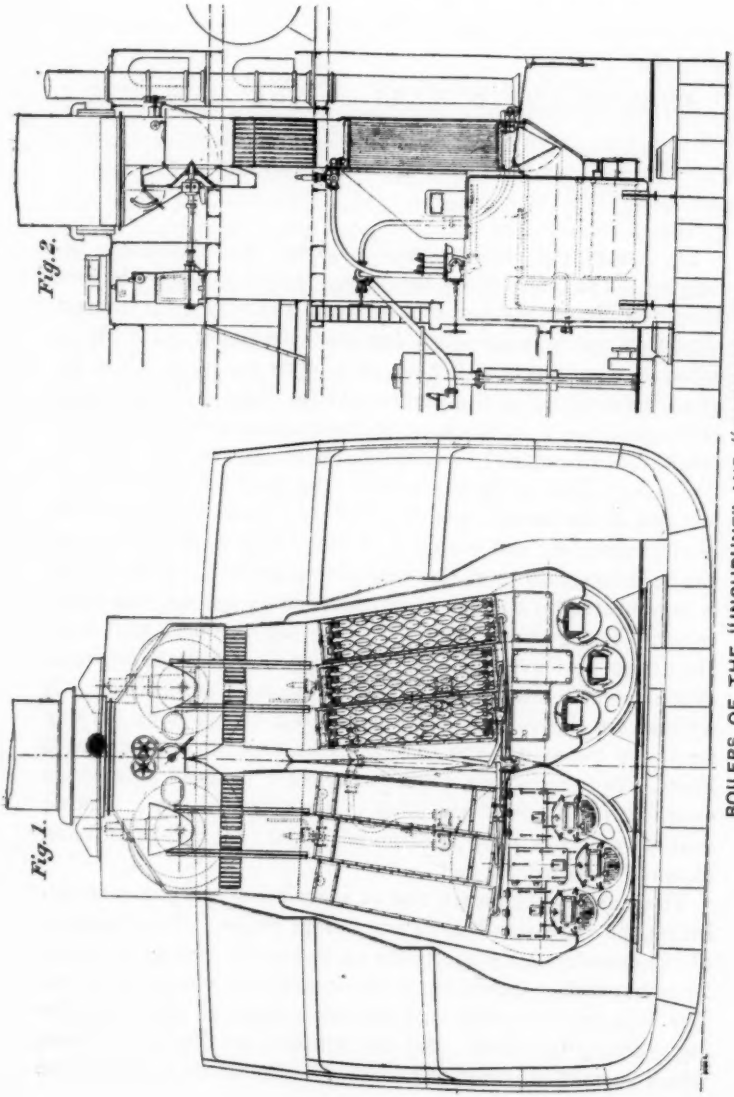
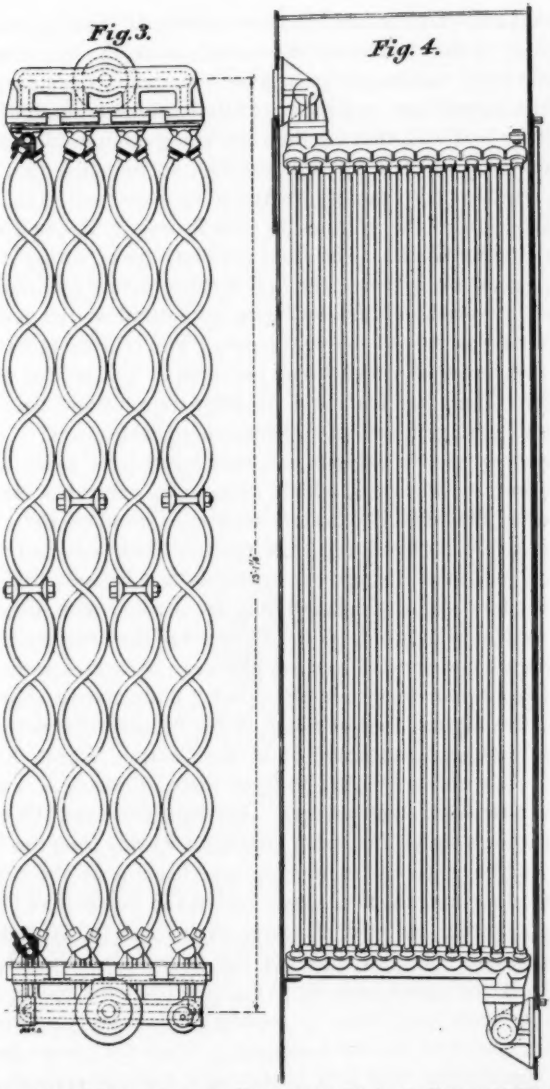


Fig. 2.

Fig. 1.

BOILERS OF THE "INCHDUNE" AND "INCHMARLO."



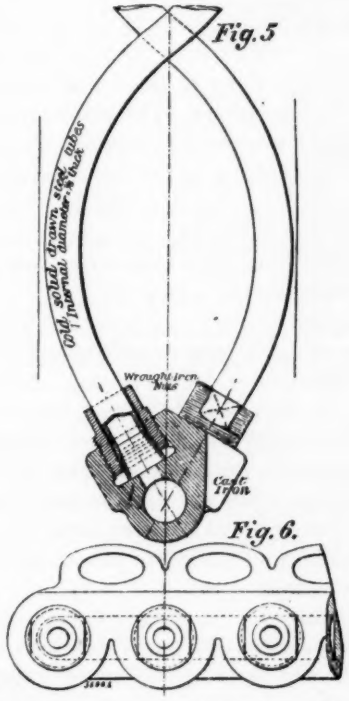
SUPERHEATERS OF S. S. "INCHDUNE" AND "INCHMARLO."

high-pressure, which is lined, but not jacketed. Special care has been given to this feature of the arrangement, the cylinders being completely enveloped by a jacket of steam, on sides, tops and bottoms, and over and above is fitted a thick lagging of non-conducting material, that on the tops being composed of asbestos blankets protected by iron casings, so adjusted that they can be removed with facility for the purpose of overhaul. The general design of the engines is that in vogue at the Central Marine Engine Works. The front columns are of wrought iron, the high-pressure cylinder, the first mean-pressure cylinder, and the first low-pressure cylinder being supported at the back on columns cast as part of the condenser. The remaining two cylinders rest, as usual, on cast-iron columns of box section on the bedplate. There are ten main bearings supporting the crankshaft, which is composed of five interchangeable parts.

Interesting as the engines are, they must give place to the boilers and superheaters, which, of course, were also made at the Central Works. The boilers are two in number, and 13 feet in diameter by 10 feet long. On the trial they provided steam for 1,600 indicated horsepower without the slightest difficulty.

The boilers are single-ended and are worked with Ellis and Eaves' system of induced draft. They are of the ordinary Scotch type, but are constructed to carry the very high pressure of 267 pounds per square inch. In the uptake, immediately above the level of the highest row of tubes, is the "Central" superheater, a device designed and patented at the Central Marine Engine Works. It consists (Figs. 1 to 6) of three divisions, in each of which are two cast-steel headers. Between these are 168 waved tubes, through which the steam passes on its way from the boiler to the engine, entering at the top and leaving at the bottom. The waved form of the tubes insures that the steam shall be continually agitated, and that all parts shall come in contact with the hot metal. The lower part of the waved pipes is naturally hotter than the upper part, for the gases from the boiler strike here, and hence the steam is heated progressively, while the gases are cooled in the same manner. When they leave the top of the superheater they flow up through nests of vertical pipes

to the fan, by which they are aspirated and forced into the funnel. These vertical pipes heat the air which is drawn into the furnaces by the fans, the air entering through openings in the casings, and flowing downwards among the pipes, and thence to the ash pits.



DETAILS OF SUPERHEATERS S. S. "INCHDUNE" AND "INCHMARLO."

Fig. 7 gives a series of diagrams for all the cylinders, together with a combined diagram. It is to be noted that no attempt was made to balance the power of the engines on the first trip when these diagrams were taken. The powers developed in the various cylinders were as follows:

	Horse-power.	Mean pressure.	Range of temperature.
		Pounds.	*Deg. Fahr.*
High-pressure cylinder	283	75·3	55½
First intermediate-pressure cylinder	359	47·775	59½
Second intermediate-pressure cylinder	300	19·95	45½
Forward low-pressure cylinder	329	14·35	107
After low-pressure cylinder	356	15·525	107

It will be seen that there is some wiredrawing in the first cylinder due to the superheater. This will be remedied in future engines. The dotted areas in the combined diagram follow very closely the $P V^{\frac{1}{9}}$ curve down to the low-pressure diagram, after which they conform more closely to the $P V^{\frac{17}{16}}$ curve. The total area of the actual diagram is 87·9 per cent. of the standard area of reference A B C D E, taken between the upper and lower limit of pressure registered by the indicators.

The boilers are fitted with Serve tubes and arched ribbed furnaces. The use of Serve tubes enables smaller boilers to be employed than otherwise would be needed. The high pressure necessitates the use of a very thick shell ($1\frac{19}{32}$ inches) and very stout stays. The shell is made of three plates, butt-jointed, with covering plates inside and out. The shell is flanged at each end, and to render this possible the plates are welded for a short distance. Great pains have been bestowed on the lagging of the boilers and steam pipes, since at such pressure the losses by radiation may be very great.

Other novel features in the design of this installation are the means employed to heat and purify the feed water before it enters the boilers, and the trapping of the water condensed in the cylinder jackets. In high-pressure boilers, such as those used, too much attention cannot be given to the treatment of the feed water before it enters the boilers. It must be of as high temperature and as free from impurities as is economically possible, and it is also highly important that the internal surface of the boiler should be protected against oxidation, and for this reason the air held in suspension in the feed water should be got rid of. To effect this the feed is, in the first place, pumped

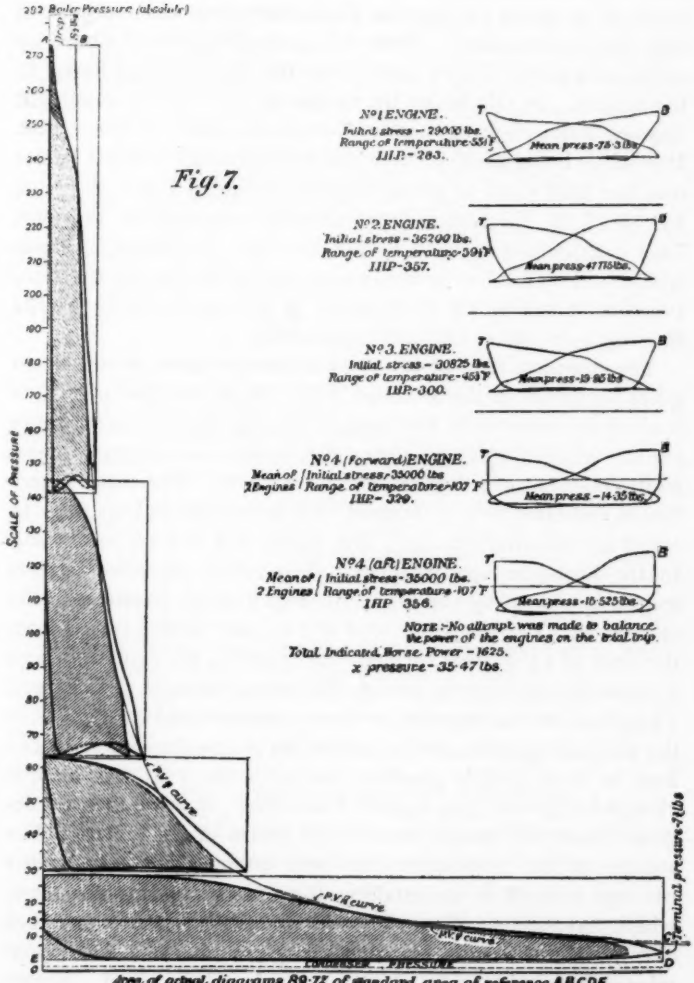

292 Boiler Pressure (absolute)
SCALE OF PRESSURE
PV^n curve
Terminal pressure 7 lbs
N°1 ENGINE.
Initial stress – 29000 lbs.
Range of temperature 351°F
IHP – 283.
Mean press 7.6 3 lbs.
N°2 ENGINE.
Initial stress – 36700 lbs.
Range of temperature 391°F
IHP – 357.
Mean press 4.7 15 lbs.
N°3 ENGINE.
Initial stress – 30825 lbs.
Range of temperature 463°F
IHP – 300.
Mean press 9.95 lbs.
N°4 (Forward) ENGINE.
Mean of 2 Engines
Initial stress 35000 lbs.
Range of temperature 107°F
IHP – 329.
Mean press. – 14.35 lbs.
N°4 (aft) ENGINE.
Mean of 2 Engines
Initial stress 35000 lbs.
Range of temperature 107°F
IHP 356.
Mean press 15.525 lbs.
NOTE :- No attempt was made to balance the power of the engines on the trial trip.
Total Indicated Horse Power – 1625.
x pressure – 35.47 lbs.

Fig. 7.

Area of actual diagrams 89·72 of standard area of reference A.B.C.D.E. taken between upper and lower limits of pressure registered by indicators.

COMBINED INDICATOR DIAGRAM S. S. "INCHDUNE" AND "INCHMARLO."

from the hotwell through a contact heater where its temperature is raised to about 223 degrees Fahrenheit, and where any air it may hold is eliminated. From this contact heater it is passed by means of a pair of Weir's feed pumps through a surface heater to the boilers. In this heater the temperature should be about 400 degrees Fahrenheit, or nearly that of the steam in the boiler. It is while being pumped from the hotwell to the contact heater that the feed water is passed through a pair of filters, designed by Mr. J. B. Edmiston, superintendent engineer of the line. This enables the water to be put through the filtering process whilst still under low pressure and at a comparatively low temperature, a fact which contributes in no small degree to the filtering being more efficiently performed.

The complete data of the cycle of temperatures in these engines are given in the annexed Table, where the gradual rise in heat of the water from the hotwell at 96½ degrees, through the contact heater (113 degrees) and the surface heater (370 degrees) to the boiler at 412 degrees, can be followed. The steam enters the superheater at 412 degrees, and leaves at 469½ degrees to begin its downward course; first losing 22½ degrees on its way to the high-pressure chest, and then being expanded in four stages, as shown by the diagrams, Fig. 7, until it returns to the condenser. The temperature of the air can be also traced from the deck at 53 degrees through the heater to the furnace, which it enters at 299 degrees, leaving the smoke tubes at 587 degrees. The gases lose 44 degrees in the superheater and 41 degrees in the air-heating tubes, and enter the fan at 404 degrees. All the heat is saved that is possible, the temperature at the fan discharge being only 319 degrees Fahrenheit, or more than 90 degrees below the temperature of the steam in the boilers. The success of the installation has been attained not only by the courage evinced in undertaking the use of superheated steam, which has been so often tried and so uniformly abandoned, but also by infinite care in securing a large number of small economies, which add up to a very considerable amount. Superheated and high-pressure steam has its own special sources of loss, and if these are not guarded against most carefully, it is quite possible that they may quite equal the theoretical gains.

LIGHT TRIAL IN BALLAST TRIM OF S. S. *INCHMARLO*, OCTOBER 26, 1900.

Draught, forward, feet and inches	10– 4
aft, feet and inches	15– 5
mean, feet and inches	12–10½
Reversing and expansion gears	Full out.
Intermediate stop valve on engine	Full open.
Steam stop valves to and from superheater	¾ open.
Pressure of steam in No. 2 cylinder jacket and covers, pounds	103
Nos. 3 and 4 cylinder jacket and covers, pounds	68
Temperature of superheated steam in jacket coil of No. 2 receiver chest, degrees Fahrenheit	470
Feed temperatures:	
Hotwell, degrees Fahrenheit	96½
Inlet to contact heater, degrees Fahrenheit	113
Outlet from contact heater, degrees Fahrenheit	209
surface heater to boilers, degrees Fahrenheit*	310 to 370
Temperature sea water, degrees Fahrenheit	54
discharge, degrees Fahrenheit	97
deck, degrees Fahrenheit	53
engine room, degrees Fahrenheit	75
stokehold, degrees Fahrenheit	77½
heated air entering furnaces, degrees Fahrenheit	299
waste gases below superheater, degrees Fahrenheit	587
above superheater, degrees Fahrenheit	543
heating tubes, degrees Fahrenheit	404
at fan discharge to funnel, degrees Fahrenheit	319
steam at inlet to superheater pipes (267 pounds), degrees Fahrenheit	412
steam after passing through superheater, degrees Fahrenheit,	469½
total superheat above temperature due to boiler pressure, degrees Fahrenheit	57½
steam at high-pressure steam chest, degrees Fahrenheit†	447

* The fluctuation of temperature of feed to boilers was due to the trapping arrangements being insufficient in size.

† Drop in temperature between superheater and engines due to insufficient lagging.

In connection with the jacketing of the cylinders, one very important point to be considered in aiming at economy in steam is the trapping of the condensed water. Hitherto this has been a source of great waste, as, when the traps are not in working order, steam, as well as the condensed water, escapes. To combat this waste and to effect as perfect trapping as possible, the Central Marine Company have designed and patented a special trap which has, it is thought, the merit of being novel. It may

be described as being a positive-action trap; it depends for its action upon a reciprocating internal piston, lifting the valve from its seat by means of the water trapped. If no water be in the trap, no lift takes place, whereas if water fills the trap, the valve, of necessity, must lift.

On the trials, the efficient working of these traps was proved by the dryness of the jackets and the temperature of the water in the drain pot into which the traps led, the one showing that no water was lodging in the jackets, and the other that no steam was passing from the jackets.

Every credit is due to Messrs. Hamilton, Fraser & Co. for being the pioneers in such a decided departure in marine engine practice. It is interesting to note that the Central Marine Works are at present fitting an exact duplicate of this machinery into the new steamer *Nassovia*, for the Hamburg-American Line.

NOTES.

NINETEENTH CENTURY IN A NUTSHELL.

This century received from its predecessors the horse; we bequeath the bicycle, the locomotive and the motor car.

We received the goose quill and bequeathed the typewriter.

We received the scythe and bequeathed the mowing machine.

We received the hand printing press; we bequeath the cylinder press.

We received the painted canvas; we bequeath lithography, photography and color photography.

We received the hand loom; we bequeath the cotton and woolen factory.

We received gunpowder; we bequeath lyddite.

We received the tallow dip; we bequeath the electric lamp.

We received the galvanic battery; we bequeath the dynamo.

We received the flintlock; we bequeath Maxims.

We received the sailing ship; we bequeath the steamship.

We received the beacon signal fire; we bequeath the telephone and wireless telegraphy.

We received ordinary light; we bequeath Roentgen rays.—"Answers."

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Forty-second Annual Meeting.

The first session of the forty-second meeting of the American Society of Mechanical Engineers was opened Tuesday evening, December 4th, at the society rooms, 12 West Thirty-first street, New York, with an unusually large attendance. The annual address, "Some Landmarks in the History of Rolling Mills," was delivered by President C. H. Morgan, who presented in a very comprehensive manner the growth of the industry of rolling mills and its influence on the railroads and civilization. The

early part of the second session was taken up with the business of the society and the annual election of officers. The election resulted as follows: President, Samuel T. Wellman, of Cleveland, O.; Vice-Presidents, Arthur M. Waitt, of New York, James M. Dodge, of Philadelphia, and Ambrose Swasey, of Cleveland; Treasurer, William H. Wiley, New York; Secretary, F. R. Hutton, New York.

On Thursday the fourth session was held at Havemeyer Hall of Columbia University, upon special invitation from President Low. After the reading of papers in the morning the society was the guest of the University for the remainder of the day.

The first paper presented at this meeting was "Comparison of Rules for Calculating the Strength of Steam Boilers," by Mr. H. De B. Parsons. Both the paper and the discussion which followed showed clearly the differences in the several rules now used in determining the strength of the different parts of a steam boiler. The sentiment was that the United States Government rules are faulty, and that it is better to use the foreign rules, or those of the American insurance companies. A motion was passed to the effect that the council consider the appointment of a committee to look into the matter of adopting uniform rules.

Mr. Charles T. Porter, in his paper, "A Record of the Early Period of High-Speed Engineering," traced the early history of the high-speed engine by an interesting account of the life of the late John F. Allen, who had to do directly with the development of the high-speed engine, and bringing into practice the steam engine indicator.

"The Steam Engine of Maximum Simplicity and Highest Thermal Efficiency," a paper by Dr. R. H. Thurston, was a history of the development of the steam turbine, giving definite facts as to the efficiency established by various tests, and was discussed from the standpoint of cost, exacting work required to build steam turbines and their application to marine propulsion. (An abstract of this paper is given in this number of the JOURNAL.)

Mr. Wm. Sangster, in his paper, "Note on Centrifugal Fans

for Cupolas and Forges," lays much stress on the importance of the method of applying fans to widely differing installations, and as to establishing a fixed rule covering the ground for all installations, it would be impossible. The paper offers several formulas for computing the power required by centrifugal fans in cupola and forge practice, treating separately, cupola fans, forge fans, and smoke exhausters. The relation of outlet pressure to outlet area of fans was also considered.

Considerable discussion, both oral and written, followed the presentation of Mr. F. W. Dean's paper on "A Power Plant of the Massachusetts General Hospital." The paper, though criticised from the standpoint of certain features of the plant, was valuable in that it brought out from those present the experiences in up-to-date operations.

The next paper presented was on the "Construction of Contracts," by Mr. R. P. Bolton, and contained a copy of the "Uniform Contract," adopted and recommended by the Institute of Architects and National Association of Builders, which the author severely criticises, and also suggests necessary conditions which should be included in this contract.

The concluding paper of the evening was that of Mr. E. T. Adams, "An American Central-Valve Engine," which received a careful and somewhat limited discussion. The paper is a descriptive argument in favor of the principal characteristics of the central valve engine. The author tells what an engine of this type, designed for a wide field of service, should be. The engine must have moderate speed, must be of the vertical type, because it requires less floor space, single-acting, to comply with limited head room; it must have a central valve, because it allows ample port opening with very low clearance and affords practically perfect drainage of the cylinders, and it must be compound if the gain in economy shall justify the expense. The paper also gives a brief description of the valve gear.

As was previously announced, the Thursday morning session was held at Havemeyer Hall, Columbia University, and the first paper of the morning being a description of "A Mechanical Integrator Used in Connection with a Spring Dynamometer," by

M. H. Wickhorst, designed by the author for use on the Chicago, Burlington & Quincy Railroad dynamometer car for the purpose of automatically and autographically showing the average draw-bar pull. The mechanical integrator consists of a registering wheel, which slides backward and forward in sympathy with the dynamometer springs, and a circular disk, making in this case nearly three revolutions per mile, and on which the registering wheel slides. The registering wheel is a small steel wheel 2 inches in diameter, and the disk is brass, 11 inches in diameter. The wheel is so placed that when there is no compression of the springs it stands on the center of the disk. Its plane is at all times at right angles to the line of motion of the spring compression. Thus the farther the wheel gets from the center of the disk, the more revolutions will it make for a given number of revolutions of the disk. The sliding of the wheel back and forth on the disk causes no revolving of the wheel. Only the turning of the disk causes the wheel to revolve, and in proportion to the distance the wheel is from the center of the disk. The discussion on this paper was with regard to the interpretation of these records, which were not explained fully in the paper. Mr. R. H. Soule offered a ready means of reading such diagrams.

Mr. C. A. Read's paper presented "An Apparatus for Dynamically Testing Steam-Engine Indicators" and brought out a discussion on the care of indicators, methods of allowing for errors after the errors were determined, and the advisability of oiling the piston of an indicator.

The following paper, "A New Recording Air Pyrometer," by Mr. W. H. Bristol, was descriptive of an instrument invented by him for measuring temperatures of high ranges, and to give continuous records of changes of such temperatures on a moving chart. The paper was a most interesting one, as was evident from the liberal discussion which followed its presentation. The highest temperature at which the author has had experience with his instrument is about 2,200 degrees Fahrenheit, but he says he sees no reason why it should not be successful up to 3,000 degrees Fahrenheit.

Mr. F. M. Wheeler then read his paper, entitled, "Comparative Value of Different Arrangements of Suction Air Chambers on Pumps," in which he shows that an air chamber is just as necessary on the suction end of a pump as on the delivery end, if the noise and severe effect of water-hammer is to be avoided. He also insists on the importance of the proper location of the air chamber.

The opening paper of the final session was that of Prof. W. F. M. Goss, on "Tests of the Boiler of the Purdue Locomotive." *

The next paper was by Mr. W. B. Gregory, on "Tests of Centrifugal Pumps," which gives by diagrams the results obtained from tests made on two centrifugal pumps, one with a 2½-inch suction pipe and a discharge pipe 2 inches in diameter. The large pump had a discharge pipe of 25 inches and two suction pipes, each 36 inches in diameter.

Mr. W. J. Keep then presented a paper on the "Hardness or the Workability of Metals," in which he considers the development and results of a machine perfected by himself for testing and recording by diagrams the workability of metal specimens. The author also gives results obtained from the machine.

This paper was followed by one on the important subject, "A New Principle of Gas Engine Design," by Mr. C. E. Sargent. The author gives an account of the development of a gas engine designed by himself to meet not only the requirements of prime movers, but to be simple and cheap in construction and easy of operation. The principal feature of the engine, besides having two tandem cylinders, is its interesting method of governing, which is different from that of the usual engine, in that the explosive mixture is not admitted the entire length of stroke, but cut off at a point somewhat less than half stroke and expanded for the remainder of the stroke. On the return, it is compressed from the point where cut-off took place. The discussion which followed the presentation of this paper was complimentary to the various features of the design of the engine, commenting particularly on the considerably reduced pressure and temperature of the exhaust.

* This paper is printed in full in another part of this number of the JOURNAL.

Mr. C. V. Kerr's paper, "Heat Efficiency of a Gas Engine as Modified by the Point of Ignition," described tests made at the Armour Institute of Technology, on a Fairbanks-Morse gas engine. The discussion of this paper, as well as the following one, was limited to those presented in writing, which were not read, but handed over for publication in the transactions of the society.

"Power and Light for Machine Shop and Foundry" was the concluding paper of the meeting and was read in part and commented on by the author, Mr. F. R. Jones. This paper describes some extensive investigations recently made by the author on two power plants, with regard to electric power transmission and light. A large number and variety of tools were tested to determine the power required to drive these various machines. The paper gives in table form some of the derived data in this connection.

THE STEAM TURBINE, THE STEAM ENGINE OF MAXIMUM SIMPLICITY AND HIGHEST THERMAL EFFICIENCY.

[Abstract of a paper by Robert H. Thurston, Member American Society of Mechanical Engineers.*]

Prof. Thurston states that while the ideal thermodynamic machine has not been constructed, and probably never will be, the close of the nineteenth century sees a remarkably close approximation to the ideal machine. The ideal construction is certainly reached in a machine in which there exists but a single moving element and the ideal thermodynamic machine is approximated in a motor in which adiabatic expansion is secured, and friction and heat waste may be made sources of comparatively small loss. The elements of waste, conduction and radiation, and incomplete expansion, are probably capable of large reduction, with improved construction and continued experience in the apportionment of the apparatus to its work. The main purpose of this discussion is to summarize the work of the steam turbine to date, bringing out into relief facts indicating the essential importance of employing superheated steam in a ma-

* From "Marine Record," December 27, 1900.

chine in which it has seemingly no other than thermodynamic value, and of the use of condensation to enable the engineer to evade a loss and accomplish a purpose which have no counterparts in the case of the piston engine. Prof. Thurston presents the following conclusions: 1. The steam turbine thermodynamically approximates in its real form more closely to the ideal than does any other type of heat motor. Its cycle lacks only the introduction of the Carnot compression. 2. It is entirely free from that waste which in the real steam engine of common type constitutes usually, if not invariably, the most important of its extra thermodynamic losses. 3. It is peculiarly well fitted for use with those very high steam pressures as we now regard them, which must ultimately probably be resorted to by the engineer designing heat engines in his endeavor to further improve the efficiency of that class of motors. 4. It is only limited in speed of rotation by the strength of its materials of construction. 5. It is especially suitable for use with superheated steam, it having no rubbing parts on which lubrication may be difficult, in presence of superheated steam, and the limit to the superheat, so far as the motor is concerned, being only found at that point at which increased temperature of metal produces reduction of tenacity in objectionable amount. That limit, not as in earlier days of lubrication with animal oils, and still with other engines, is fixed with this machine at the boiler. 6. As to its operation, it is obvious that friction is peculiarly active for evil in this motor, and that small diameters of journal, freedom from contact of part with part, except as absolutely required by the construction, and minimizing fluid friction by superheating steam, and by securing as complete removal of the atmosphere, air or vapor, from about the revolving wheel as practicable, must be carefully sought in order that the mechanical efficiency of the machine shall be made a maximum. 7. The wastes of the steam turbine are all extra thermodynamic; the loss due the absence of adiabatic re-compression excepted. They consist of journal friction, which is made minimum by the use of a flooded bearing and a light unguent; fluid friction between disk and leakage steam, or suspended moisture in the jet,

which may be made a minimum by superheating, and between the disk and its enclosing atmosphere of vapor, which may be minimized by the employment of a good condenser; loss of heat and steam by leakage, which may be reduced to a minimum by durable material, fine workmanship and close fits; waste by incomplete expansion, which may be reduced to a limit determined by the finance of the case, by the resultant increase of friction, and of cost due the necessary enlargement of the turbine; and, finally, thermodynamic waste by failure to secure that complete adiabatic re-compression of the fluid which is necessary to convert the Rankine-Clausius' into that of Carnot. The latter is a peculiarly difficult matter with the steam turbine, since it probably necessarily involves the employment of a separate vapor compression pump of special character, and an amount of added work and cost which may introduce losses more than compensating its gains.

PROGRESS OF TURBINE PROPULSION.

An important step in the development of the turbine-propelled vessel has just been taken in the signing of a contract for the construction of a large turbine-propelled passenger steamer for use on the Firth of Clyde. The vessel is to be 250 feet in length, 30 feet in beam, and 11 feet in molded depth, and she is to attain a speed of 20 knots with turbine engines of 3,500 to 4,000 horsepower. Power will be developed on three shafts, by a compound turbine; one high-pressure on the center shaft, and two low-pressure turbines on the side shafts. The determination to construct a vessel of this size will be welcomed by the builders of deep-sea steamers, for it forms the next logical step in a development which commenced with the little *Turbinia*, and was carried on in the 380-ton *Viper* and *Cobra*. We understand that probably a contract for a large cross-channel steamer of about 2,000 tons displacement, propelled by turbines, will shortly be let.—"Scientific American."

PULVERIZED FUEL.

About ten years ago D. K. Clark referred to the use of powdered coal as "unique and interesting." It is now much more

than that, and is worthy of the most careful attention of engineers in view of its apparently very promising possibilities. The idea dates back to 1831, when Henschel carried out experiments at Cassel, Prussia, in connection with brick kilns and heating furnaces. While progress has been made continually, it was not until recently that commercial success has been attained in practical operations, but its present employment in connection with the manufacture of cement in this country and also in firing boilers both here and abroad entitle it to a consideration which it has not yet attracted.

The burning of fuel in finely divided form permits of turning the fuel into gas and obtaining a perfect and prompt intermixture of the gas and air. This constitutes perfect combustion, which is necessarily smokeless, and there is good reason to believe that the results are almost as good with poor as with good grades of coal, but, of course, the better the coal the less is required. By passing the fuel into the furnace by means of a stream of air the regulation of the elements of combustion is under perfect and convenient control, and one great advantage of the automatic stoker is attained in that there is no opening of fire doors. That the combustion may take place under ideal conditions is evident from the fact that powdered coal has been burned with the proportion of 12 pounds of air per pound of coal, which is precisely the theoretical chemical requirement. We have also records of continuous tests showing 18 per cent. of carbonic acid gas from flue-gas analysis of a powdered-fuel boiler. With such conditions as these, or approaching them, increased evaporation may be expected, and is in fact obtained, over that from the same fuel burned on grates with a necessarily large excess of air. With powdered fuel there are no clinkers and the ash is apparently as fine as the powdered coal and it may be removed through pipes.

Assurance is given that lignite will work satisfactorily when pulverized, although there are no authenticated records at hand confirming it. We have seen the fact demonstrated that very poor coal works almost as well in this process as better coal when the conditions are adjusted as they should be. There

seems to be no difficulty in igniting the powdered fuel, and while it is convenient to retain the ordinary grates upon which to start a wood fire, as a preliminary to the dust firing, they are not absolutely necessary and might be removed, but where they are retained in the boiler, the change back to grate firing may be easily and quickly accomplished if for any reason it becomes necessary. As to reliability, one experimenter informs us that he has operated a stationary boiler with powdered fuel, continuously night and day for four months, without any difficulty.

In looking for the disadvantages, two come to the front and both seem possible to overcome. First, there is the cost of grinding the coal, but this may be safely figured at 25 cents per ton or less, although several early experiments were terminated on account of the expense of this part of the process. With one type of grinder now in use one horsepower is said to be sufficient to grind 100 pounds of coal per hour. The fineness of grinding differs among the different systems, and ranges from 200 mesh to impalpable powder. Formerly great difficulty was found in grinding moist coal, but this has apparently been overcome. Second, after the completion of the combustion the ash is left floating in the gasses and it must be given time to settle or it will pass out of the stack as an annoying product. Careful examination of this matter seems to indicate that with the usual flameway supplied by the ordinary cylindrical return-tube boiler a sufficient distance is provided in which the dust will settle before going into the tubes. Probably the change of direction of the gases at the back end of the boiler contributes to this result, because in a boiler of this kind there seems to be no more accumulation of dust in the tubes than from a grate-fired boiler, and there seemed to be no evidence about the stack of any dust. It is believed that there need be no difficulty from the ash in this type of boiler, but what the experience with locomotive or marine firing may be is yet to be learned. It has been tried in both of these services, but thus far no demonstrations have been made of its complete success in either.

The fundamental principles for the successful use of powdered coal seem to be (1) a combustion chamber maintained at a high

temperature, which requires a fire-brick arch to prevent the flame from impinging at once against the heating surfaces; (2) the powdered fuel must be thoroughly mixed with the entering air, so that the air will surround the particles of coal, and the fuel must be delivered in an uninterrupted stream; (3) the particles of fuel must be maintained suspended in the gases until they are completely burned, and this requires a somewhat long flame-way, for the flame must not be chilled.

When the coal is finely divided and delivered uniformly mixed with air a solid radiating flame is produced, which at first is full of particles of solid fuel in incandescence, and these rapidly disappear, leaving the larger portion of the flame merely that of burning gas. One has only to follow this flame, as the writer has done, by means of peep-holes arranged through the brick-work of an ordinary boiler setting, to be impressed with the completeness and ideal character of the combustion. The flame is that of gas rather than oil. The fuel appears to be gasified in an intensely hot atmosphere containing the right proportion of the supporter of combustion.

Different systems handle the pulverization differently. The Germans prefer to powder the coal in one place and deliver it to the feeding machine in bags, while in this country the neater and safer process of pulverizing the coal as it is used is generally followed. A large amount of finely-powdered coal may or may not be dangerous in storage, but there seems to be a decided advantage in carrying the dust directly from the pulverizer into the furnace, because this permits of the most perfect aeration, and this is essential. The power for grinding is applied in various ways, either by belt driving from a small steam engine or by connecting a steam turbine directly to the grinder. The grinding is usually in two stages, the first bringing the coal to about the size of split peas and the second completing the process. The fine grinding seems to be accomplished best by attrition in a cylinder filled with rapidly-revolving vanes, and from this cylinder a blower takes the dust into the furnace through a tuyere, which is filled with partitions parallel to the current for the sake of obtaining the uniform mixture and for spreading and concentrating the delivery as desired.

At least four different systems seem to be giving promising and, we may say, satisfactory results. Of these the Wegener process has made considerable headway in Germany and in England. This process was described and illustrated in this journal in July, 1896.* The results of trials made on a Cornish boiler by Mr. Bryan Donkin at that time are reproduced in the accompanying table.

In the Wegener process the powdered coal is delivered to the feeder in sacks. The fire doors and ash-pit openings at the front of the boiler are closed and the natural draft of the chimney is used to deliver the coal dust to the furnace through a large duct, over which the dust hopper is mounted. In the duct is an air turbine driven by the natural air draft, and this operates a revolving sieve and a tapper whereby the dust is shaken down into the stream of air, by which it is carried into the furnace. The results of the trials indicate a decided superiority of the dust fuel over the same coal burned upon a grate a few days before in the same boiler. No extraordinary performance is claimed for the Wegener process, but this test would indicate that its commercial advantages depend largely upon the cost of powdering the coal. As far as smoke is concerned, it is perfectly satisfactory.

Another German process, the Schwarzkopff, is particularly interesting just now, because of experiments which are being conducted with it by Mr. William Renshaw, Superintendent of Machinery of the Illinois Central, upon one of the furnaces at the Fourteenth Street Power House of that road in Chicago. Mr. Renshaw is not ready to express an opinion pending the results of tests which are now under way, but he evidently considers that there is something in the process and promises the results when the tests are completed.

The Schwarzkopff feeder is attached to the furnace front and consists of a hopper containing the pulverized coal, a rapidly-revolving brush to feed the coal through an opening into the furnace, and an air opening for the control of the air. The regulation of the delivery of the fuel is had by a small hand wheel

* "American Engineer and Railroad Journal."

which controls the opening through which the dust passes to the brush.

The Ideal Fuel-Feeder Company, 164 Montague Street, Brooklyn, have been engaged for several years in developing a pulverized coal system, and the writer recently examined it as applied to a cylindrical return-tube boiler in commercial operation in Brooklyn and was impressed with the whole idea, as no one can fail to be who will take the trouble to investigate it.

The boiler is of 90 nominal horsepower and supplies steam at 80 pounds pressure. The stack temperature is about 400 degrees. The boiler was taken as it stood when used for grate firing. A small vertical stationary engine and a belt to the pulverizer completed the equipment, and a return to grate firing may be made in five minutes, plus the time required to start the grate fire. After watching the stack for two hours we can say that the combustion is absolutely smokeless as regards black smoke. There was at times a light-gray mist near the stack, but less in amount and of about the character of the whitish haze from a stack of a coke fire. Prof. D. S. Jacobus, after a test, says of it: "At times there was no smoke visible at the stack, and the smoke which did appear under some conditions of the fire was of a very light character, being in the nature of a gray mist extending but a few feet from the chimney. When working under proper conditions there was little or no smoke produced."

RESULTS OF TRIALS—BY BRYAN DONKIN.

Trial:	I.	II.
Experimental number		
Date of experiment, 1895	March 29.	April 1.
Conditions, with or without Wegener's apparatus	Without.	With.
Duration of trial, continuous, hours	7.1	6.66
Weather	Wet.	Fine and dry.
Mean steam pressure (from tested Bourdon gage every quarter hour), pounds	82	83.4
Coal:		
Total coal burned, pounds	1,600	1,410
Coal burned per hour, pounds	225	211.5
Coal burned per hour per square foot of fire-grate, pounds	16.3	.....
Moisture in coal, per cent	9.0	1.2
Ashes and clinkers in coal, per cent	14.8	Assumed at 15 to 19.

Water:		
Mean temperature of feed water entering boiler, degrees Fahrenheit	63	48.2
Total feed water evaporated, pounds	7,928	10,517
Water evaporated per hour, pounds	1,117	1,577
Water evaporated per hour per square foot heating surface, pounds	2.23	3.15
Evaporation:		
Pounds water evaporated per pound wet coal, from temperature of feed, pounds	4.956	7.46
Pounds water evaporated per pound wet coal, from and at 212 degrees Fahrenheit, pounds	5.90	9.00
Pounds water evaporated per pound dry coal, from and at 212 degrees Fahrenheit, pounds	6.48	9.11
Coloric value of coal, pounds water per pound dry coal, from and at 212 degrees Fahrenheit, pounds	12.00	11.85
Thermal efficiency of boiler = $\frac{\text{actual evaporation}}{\text{caloric value}}$, per cent	54	77
Chimney and gases:		
Mean position of damper	Full open.	Full open.
Temperature of furnace gases at end of boiler tube, degrees Fahrenheit	above 750	above 750
Temperature of furnace gases at base of chimney, degrees Fahrenheit	438	413
Draft of chimney inside flue at front of boiler, inch of water	0.41	Water gage oscillated from a slight pressure to a vacuum.
Draft of chimney at base of chimney, inch of water	0.6	
Mean analysis of furnace gases, taken every quarter hour:		
CO_2 per cent. by volume	8.72	15.35
O per cent. by volume	8.13	3.14
CO per cent. by volume	0.88	.....
Temperature of air in boiler house, degrees Fahrenheit	54	58
Smoke:		
Total number of times smoke observed	70	7
Total duration of smoke, minutes	105	6
Mean intensity of smoke (Mr. D. K. Clark's smoke scale), number	7	5

In this experiment the bars were rather too wide apart for the small coal used to get the best results.

—"American Engineer and Railroad Journal."

BURNING POWDERED COAL IN STATIONARY BOILERS.

An apparatus for burning powdered coal in a stationary boiler was seen recently in operation in a machine shop in Brooklyn, N. Y. Briefly described, it consists of a hopper in which the pul-

verized coal is put, of a revolving cylinder in the bottom of the hopper, which, it may be added, extends across the boiler front, and of a gate in front of the furnace with a row of teeth at the bottom edge and with mechanism for raising and lowering. The revolving cylinder is fitted with projections to mix up the powdered coal and brush it toward small apertures ¼ inch in diameter, in the hopper bottom, through which it falls outside of—that is, in front of—the gate. From this space the finely divided coal is carried into the furnace by the natural draft of air, and the currents of mixed air and coal are divided by the teeth at the entrance. The apparatus is operated by a small steam engine which drives the cylinder in the hopper bottom by means of a pawl and ratchet wheel actuated through a set of levers. This mechanism, however, is only brought into action when the steam pressure drops below the normal, at which time a lever is automatically pulled and the link system of the levers so placed as to give the pawl sufficient travel to engage the ratchet wheel and thus rotate the cylinder until sufficient coal is fed to restore the desired steam pressure. The apparatus is the invention of Mr. William Westlake, of Brooklyn, whose engineers and promoters are Messrs. Faber du Faur & Donnelly, of New York.

Some tests were made with the apparatus mentioned, which was attached to a No. 7½ Beggs direct-return-tubular boiler. The boiler is rated at 35 horsepower, but has 372 square feet of heating surface, which at 15 square feet per horsepower gives 24.8 horsepower. It is 40 inches in diameter, 9 feet long, with drop leg at the rear. It contains 38 3-inch tubes, 9 feet long and 20 4-inch tubes 3 feet long. The grate furnished with boiler measured 40 by 54 inches, 15 square feet, but with the powdered-coal burning attachment, had to be shortened to 40 by 34 inches, 9.44 square feet. The analyses of the coal used was as follows: Screenings, hard yard coal used on grate, particularly to start the powdered coal apparatus; water, 2.39 per cent.; volatile combustible matter, 4.86 per cent.; fixed carbon, 82.15 per cent.; ash, 10.6 per cent. Dust, of soft coal: water, 1.16 per cent.; volatile combustible matter, 29.83 per cent.; fixed carbon, 54.03

per cent.; ash, 14.98 per cent. The tests were conducted on successive days, each from 7 A. M. to 5.30 P. M. Steam pressure of the first two tests was maintained at 80 pounds, that of the third was allowed to vary—the fire rushed and then neglected—but being 80 pounds on the average; feed water was 62 degrees Fahrenheit; draft, ½ inch water, except on the third day, when it varied from ¼ to ¾ inch. The following are figures of the tests:

	Test I.	Test II.	Test III.
Dust, pounds	574	386	483
Coal, pounds	368	625	670
Total fuel, pounds	942	1,011	1,153
Total combustible, pounds	801.54	867.39	987.85
Water evaporated, pounds	8,050	8,050	7,350
Water per pound coal, pounds	8.55	7.96	6.37
Water per pound coal, from and at 212 degrees Fahrenheit, pounds	10.2	9.48	7.58
Water per pound combustible, pounds	10.06	9.28	7.45
Water per pound combustible, from and at 212 degrees Fahrenheit, pounds	11.98	11.04	8.85

In the words of the engineers: "These tests were not made to show the highest efficiency which could be obtained with the apparatus and are not to be criticised from that point of view. They were made with the idea of determining what could be expected from the apparatus when working under regular and ordinary conditions, and while the total amount of work done does not vary much from the rating of the boiler, there were times when it was much above and much below. The first day some attention was paid to burning as large a quantity of dust as the load would warrant and to burn only as much coal on the grate as was necessary. The second day the practice was reversed and the effect upon the economy is apparent. On the third day the attendance and attention was reduced to a minimum and the conditions made as adverse as it was considered would be met in ordinary bad practice, and the falling off in the result is such as may be expected from neglect and adverse conditions." The amount of coal used for banking the fire at night was estimated at 250 pounds, this being required to keep the furnace warm for 13½ hours and to raise the steam pressure from 20 or 30 pounds

to 80 in the morning. It does not enter into the figures of the tests.

The special features to which the engineers call attention are: First, that the apparatus is a satisfactory smoke consumer; second, a mechanical stoker requiring only a normal amount of natural draft and not interfering with banking the fire in the ordinary way at night; third, a control of the steam pressure amounting in its operation to a governor on the steam boiler which will act as quickly and as certain as the governor on a steam engine; fourth, the possibility of running the boiler with a high degree of economy at widely different rates of power; fifth, the operating of a plant with a minimum amount of hand labor, stated to be not more than half of what is ordinarily required; sixth, the burning of the cheapest grades of fuel without forced draft, and with very little power to drive.—"Engineering Record."

TOTAL PRODUCTION OF IRON ORE.

Previous to 1870, no iron ore statistics for the United States are complete. The figures for 1870 and 1880 are for the census years ending on May 31. For 1889 (also the census year) and all subsequent years they are for calendar years. The statistics since 1889 have been compiled by John Birkinbine for the United States Geological Survey.

TOTAL PRODUCTION OF IRON ORE SINCE 1870.

Year.	*Long tons.*	*Year.*	*Long tons.*
1870	3,031,891	1894	11,879,679
1880	7,120,362	1895	15,957,614
1889	14,518,041	1896	16,005,449
1890	16,036,043	1897	17,518,046
1891	14,591,178	1898	19,433,716
1892	16,296,666	1899	24,683,173
1893	11,587,629		

THE WORLD'S PRODUCTION OF IRON ORE AND COAL.

The following table gives the production of iron ore and coal in all countries in 1899, or for the latest year for which complete

statistics are available. Coal is the principal fuel used in the production of iron and steel, and hence deserves a place in this table. Long tons of 2,240 pounds are used in giving the production of the United States, Great Britain, Canada, Cuba, India, Natal, New South Wales and other Australasia, and "other countries," and metric tons of 2,204 pounds are used for all other countries, the latter being used as the equivalent of long tons in ascertaining the total production of all countries. As far as possible the statistics given have been obtained from official sources:*

Countries.	Iron ore.			Coal and lignite.		
	Years.	Tons.	Per cent.	Years.	Tons.	Per cent.
United States	1899	24,683,173	29.47	1899	226,553,564	31.54
Great Britain	1898	14,176,938	16.93	1899	220,085,303	30.65
Germany & Luxemburg	1899	17,989,665	21.48	1899	135,824,427	18.91
France	1898	4,731,394	5.65	1898	32,356,104	4.50
Belgium	1898	217,370	.26	1899	21,917,740	3.05
Austria-Hungary	1898	3,400,485	4.06	1898	37,786,963	5.26
Russia	1897	4,107,470	4.91	1898	12,862,033	1.79
Sweden	1898	2,302,914	2.75	1898	236,277	.03
Spain	1899	9,234,302	11.03	1899	2,742,389	.38
Italy	1898	201,260	.24	1898	341,327	.05
Canada	1899	68,891	.08	1899	4,397,367	.61
Cuba	1899	368,759	.44	.....	.....	.....
South African Republic	.....	.....	.....	1898	1,938.424	.27
Natal	.....	.....	.....	1898	387,811	.05
India	1897	43,314	.05	1898	4,136,813	.58
Greece	1898	485,159	.58	1898	17,310	.....
New South Wales	1897	234	.....	1899	4,597,028	.64
Other Australasia	.....	.....	.....	1898	1,601,968	.22
Japan	1896	27,421	.03	1897	5,647,751	.79
Algeria	1898	473,569	.56	1898	200	.....
Other countries (about)	1899	1,234,855	1.48	1899	4,849,380	.68
Total	.....	83,747,173	100.00	.....	718,280,179	100.00

THE WORLD'S PRODUCTION OF PIG IRON AND STEEL.

In the following table is given the production of pig iron and steel in all countries in 1899 or in the most recent year for which statistics have been received. English tons of 2,240

* From Department of the Interior—U. S. Geological Survey.

pounds are used for Great Britain, Canada, the United States and "other countries," and metric tons of 2,204 pounds for all other countries, metric tons being used as the equivalent of English tons in ascertaining the total production for all countries. The statistics of steel production for the United States, Great Britain, France, Belgium, Austria-Hungary, Russia and Finland, Sweden, Spain and Canada embrace ingots and direct castings, but for Germany and Luxemburg and Italy complete ingot statistics are not available and the statistics for finished steel have been used:*

Countries.	Pig iron.			Steel.		
	Years.	Tons.	Per cent.	Years.	Tons.	Per cent.
United States	1899	13,620,703	34.56	1899	10,639,857	39.25
Great Britain	1899	9,305,319	23.61	1899	5,000,000	18.44
Germany & Luxemburg	1899	8,142,017	20.66	1899	6,290,434	23.20
France	1899	2,567,388	6.51	1899	1,554,354	5.73
Belgium	1899	1,036,185	2.63	1899	729,920	2.70
Austria-Hungary	1898	1,427,240	3.62	1896	880,696	3.25
Russia and Finland	1898	2,222,469	5.64	1898	1,494,000	5.51
Sweden	1898	531,766	1.35	1898	265,121	.98
Spain	1899	295,840	.75	1899	122,954	.45
Italy	1897	8,393	.02	1898	94,667	.35
Canada	1899	94,077	.24	1899	22,000	.08
Japan	1897	57,678	.15	.....	.....	.....
Other countries (about)	1899	100,925	.26	1899	15,997	.06
Total	.....	39,410,000	100.00	.....	27,110,000	100.00

U. S. COPPER EXPORTS FOR 1900.

U. S. Copper Exports for 1900 were valued at $57,851,707, with the probability that the exports for the calendar year 1900 will exceed $60,000,000. In 1890 the copper exported was valued at only $2,349,392; and while the manufactures of brass exported in 1890 were worth only $467,313, those for the calendar year 1900 will aggregate fully $2,000,000 in value.—"Engineering News."

* From Department of the Interior—U. S. Geological Survey.

ALASKAN COPPER DEPOSITS.

Alaskan Copper Deposits are reported upon by B. F. Millard, of Chippawa Falls, Wis., who has been in the copper country of Alaska since 1898. According to his story, the copper mines in the Copper River region will exceed in output any yet discovered in the world. Near Chittyna, he says, he found extensive veins of copper yielding 85 per cent. of ore; and this vein has been located for five miles in length and to a depth of 160 feet; he estimates that if worked to a depth of 100 feet only it would yield $780,000,000 at the present price of copper. He found other deposits averaging 68 per cent. and 40 per cent. down to 13 per cent. As the Calumet and Hecla ores only figure at $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent., and the mines are some thousands of feet deep, these estimates for Alaska seem incredibly large. — "Engineering News."

COAL IN JAPAN.

The development of the coal mining industry in Japan is remarkable. A few years ago that country was dependent upon other countries for this article in order to drive industrial machinery, to provide fuel for her merchant marine and her navy. Now this order of things is completely changed. Sufficient coal can be obtained from the native mines to supply the whole country's necessities. The principal coal mining centers are in Hokkaido or northern island and in Kynshu in the south of Japan. Some idea of the present proportions of the industry may be gathered from the fact that the Hokkaido Colliery Company during the first six months of the present year earned a profit equivalent to about $775,000. Of this amount, $160,000 was set aside for the purpose of installing the necessary plant to manufacture coke, since the coal has been found to be excellent for this purpose. But the high price of European coal has caused considerable discontent in mining circles in Japan. At the present time Cardiff coal on the Japanese market is sold at $22 per ton, while the native product fetches only $6 per ton. This state of affairs has been proved to be entirely due to the

reckless competition that exists among the small coal merchants; and with a view to surmounting the difficulty, it was decided to form a combination among the colliery owners, and to suspend the sale of coal for two months, so that a consequent rise in price might ensue in the retailing of the coal. It was also decided that the minimum price of the coal be increased to $8 per ton. For a short time, therefore, Japan will suffer from a scarcity of coal, an effect which the colliery owners anticipate will result in a substantial increase in price.—"Scientific American."

THE GREATEST IRON-ORE MINE IN THE WORLD.

With a record to its credit of 1,000,000 tons of iron ore mined during the past twelve months, the Norrie mine on the Gogebic range may be considered the greatest iron-ore producing mine in the world. This output represents about one-fifth of the annual ore supply of the Carnegie Steel Co , Limited.

The Norrie mine has been in operation during the past fifteen years. Several years ago the Oliver Mining Co., under which name the ore plants of the Carnegie interests are operated, obtained control of the Norrie mine, and since that time there have been wonderful improvements in the methods of mining and handling the ore and preparing it for lake shipment to the Carnegie docks at Conneaut. More than 3,000 tons of ore are mined and shipped each working day of the year.

The railroads which carry the product to the docks have been brought to the very mouths of the mine. The "skip" cars which convey the ore from the mine dump their contents into immense ore pockets, which in turn empty into the railroad cars waiting beneath to receive their load. When there is an over supply of ore, the surplus is dumped on the stock pile. Mining never ceases. The aspect of the Norrie mine is very different from that of the Menominee range, where great ore pits can be seen. The Norrie is a mine in the true sense of the word; for there is no open pit, no evidence of the ceaseless activity far beneath the surface.

The mine now known as the Norrie includes workings in

which were four separate mines formerly known as North, East and West Norrie and the Pabst. Two additional mines, the Vaughn and the Aurora, are also operated by the company under the name of Norrie, but their product forms a separate account. If the output were included with that of the Norrie, the sum total would be much in excess of 1,000,000 tons per year.—"Scientific American."

40,000-TON CAPACITY ORE DOCK OF THE GREAT NORTHERN RAILWAY, AT WEST SUPERIOR, WIS.

The large iron-ore shipping docks of the American Great Lake ports are a class of timber construction of which, it is safe to say, no other country affords a corresponding example. Like the large ore carriers of the Great Lakes fleet and the steel car of 100 tons capacity and upwards, they have developed out of the requirements of shipping annually the 16,000,000 tons output of the Lake Superior iron mines to Chicago and the Ohio lake ports, whence it is distributed to the blast furnaces of Illinois, Ohio and Pennsylvania. Probably the largest of these docks so far constructed is the one completed early last year for the Eastern Minnesota Railway, of the Great Northern system. This dock is located at West Superior, Wis., and has a storage capacity of 40,000 tons of iron ore at one time. In addition to the interest which this dock attracts because of its size, it is an excellent example of timber-work designing for structures of this class.

In this connection it may be desirable to note that we have retained the usage of the word dock to mean the timber structure carrying the ore pockets and railway tracks alongside of which the vessel is berthed. Strictly speaking, the word dock means an inclosed water space in which a ship floats while being loaded or unloaded, as the space between two wharves or piers. By extension the word has also come to mean any space or structure in or upon which a ship may be berthed or held for loading, unloading, repairing or safe keeping, such as depositing docks, dry docks and floating docks. Accurately speaking, there-

fore, the structure which we describe here is an ore pier rather than an ore dock, and we have retained the latter designation only in deference to popular usage.

Briefly stated, the dock is 1,500 feet long, 63 feet 4 inches wide, and 73 feet high from the surface of the water to the base of the rails of the ore tracks, which run on top. On each side there is a row of ore pockets capable of holding 160 tons of ore each. Each pocket is provided with hinged spout which is lowered to discharge the ore by gravity into the vessels berthed alongside, and which is raised out of harm's way when not in use. The ore trains from the mines discharge their loads into the pockets through the traps between the tracks.

Construction was begun on the dock on January 1, 1900, and it was completed ready for operation on May 1. The timber-work was designed and erected by the engineer department of the Great Northern Railway; the spouts were manufactured by the American Bridge Works, of Chicago, Ill., and Pettibone, Mullikin & Co., of Chicago, Ill., furnished the spout hoists. We are indebted to Mr. John F. Stevens, Chief Engineer, Great Northern Railway, for the matter from which this description has been prepared.—"Engineering News."

HANDLING CARGO BY MACHINERY.

Electric Freight Conveyers for Loading and Unloading Vessels.

Up to within the last four years every pound of freight which was sent abroad was handled by means of slings or staging from the wharf immediately alongside of the vessel, says the "Scientific American." Not only is the process necessarily slow—not many sling loads can be handled per hour, even under the most favorable conditions of weather and tide—but it is very expensive, requiring as it does a large number of men to load a ship with reasonable quickness. Moreover, in the slinging of cargo, so many packages are broken that the loss of goods is not inconsiderable.

But during the last four years the method of stowing cargoes has been greatly improved by the invention and perfection of a

portable electric ship and warehouse conveyer, an apparatus which requires neither staging nor the hoisting of sack or package cargo. So rapidly does this new invention work that a ship can now be loaded in about half the time required under the old system, with the same or less number of men employed. The system is at present widely used on Puget Sound. The stowing of 1,000 sacks of grain or flour per hour or 600 tons per day of ten hours is considered an exceptionally good day's work in hoisting or slinging, or by staging; but the same number of men with a conveyer will handle 2,000 or 2,200 sacks per hour. Indeed, it may be stated that the conveying capacity of the machine is governed only by a ship's facilities for receiving cargo.

In large modern ships or in tramp steamers, where the crew in the hold can be increased many fold, sack and package cargo may be handled at a rate of from 3,500 to 4,000 packages per hour.

Especially serviceable is this invention in the loading of flour, grain and other perishable cargoes in wet weather. For, since no hoisting gear is needed, tarpaulin or canvas covering can be placed over the hatches, and stretched from the ship's rail to the warehouse door before the hatches are removed and the conveyer placed in position, thus insuring absolute protection to the cargo on the conveyer or in the hold.

All freight which can be handled in slings can be transferred by this conveyer. The saving in claims for damaged cargo has often been noticed at the offices of the underwriters.

The machine is the invention of Capt. W. L. McCabe, of the stevedoring firm of McCabe & Hamilton, Tacoma and Seattle, Wash. In the longitudiual central space formed by a strong iron or steel double truss, from 45 to 60 feet long, according to local requirements of docks or warehouses, an endless rubber or canvas belt or apron 24 inches wide is mounted, to which belt cleats may be riveted. The belt picks up the packages on the wharf or warehouse floor and deposits them at the ship's rail. The maximum inclination of the conveyer is about 50 degrees. The belt is driven by an electric motor on the frame of the machine, the motor being so placed that it will be entirely cleared

by the belt or working parts of the conveyer, thus insuring safety in operating. The conveyer is mounted on a pair of swivel ball-bearing wheels in the center, whereby it can be easily and rapidly moved to or from any part of a dock or warehouse. Only three men are required to shift it to and fro. Since the machine carries its own driving mechanism, it follows that the rise and fall of the tide or the wash of passing steamers cannot hinder the rapid loading or unloading of a cargo. The conveyer weighs about 2,500 pounds per 45 feet.—"Marine Journal."

THE CRYOLITE OF GREENLAND.

In 1850 the Danish government held in Copenhagen an exhibition of Eskimo tools and products from their distant colony in Greenland. Among the implements shown were a number of stone sinkers, which the natives had used for their nets, some of which sinkers were made from a white, translucent mineral. Dr. Hartman, a scientist, noticed these, and having secured a specimen analyzed it and found it to be the rare and valuable mineral cryolite.

During the following year the Danish government made investigations, and discovered a large deposit near Ivigtuk, on the west coast of Greenland, in latitude 62 degrees 13 minutes. Strangely enough, the Eskimos had chosen the ground above the deposit for a fishing village, and the fact that they used blocks of cryolite for the foundations of their tents probably led to its discovery. Fourteen years later, Dr. Julius Thompson commenced mining, and the industry has steadily grown in importance ever since.

In the early days of the cryolite industry, the greater part of the output was used for the production of aluminum. Bauxite soon supplaced it in that line, and then it was found that from no other material could alum and sodium carbonate be made so cheaply and so pure. The Pennsylvania Salt Company accordingly contracted for the whole output for that purpose, and mining on a large scale began. About this time some experiments were made with cryolite in the endeavor to make from it a trans-

parent glass. They failed, but a beautiful opaque porcelain-like substance was the result; far cheaper than and as beautiful as china. By merely melting a mixture of cryolite, sand and zinc oxide, this material is formed, and ware of any desired shape can be stamped from it. It is so tough that cups and plates made from it can be thrown down violently without breaking.

Very lately cryolite has been used once more in the manufacture of aluminum. By means of a powerful current it is melted, and the corundum, Al_2O_3, which forms the source of the metal, is dissolved and decomposed within it.

It can be easily seen how great an economic value cryolite possesses and of what importance it is in the arts; and as the Greenland deposit is the only one in the world at which it occurs in workable quantities, the Ivigtuk mines have naturally become of great importance.

Arlssuk Fiord, which leads from the ocean to the mines, is a narrow strait between snow-covered granite mountains. The inland ice reaches almost to it, and bergs and pack ice close it to navigation for nine months of the year. It is so deep that vessels in the harbor can fasten their bows to the rocky walls and get no soundings from the stern.

The product of the mines, amounting to many thousands of tons a year, is all shipped to the contractors by means of a small fleet which plies between Philadelphia and Ivigtuk. Even in the middle of summer the ocean near the Greenland shores is full of icebergs, and navigation is difficult and dangerous. It happens every few years that some unfortunate vessel, delayed by adverse winds at Ivigtuk, is caught in the pack ice and forced either to return to the mines or winter in the ice.—"Scientific American."

THE PRODUCTION OF ALUMINUM.

How rapidly the aluminum industry has developed in recent years is very well shown in the tabulated statement below, given a short time ago by Mr. Joseph A. Steinmetz in the course of a lecture delivered before the Franklin Institute. It shows the aluminum production of the world during the past dozen years,

expressed in tons of 2,000 pounds, and also of the United States separately, the latter figures having a special interest in view of the fact that it is in the United States and in France that the industry is making most progress.

	United States.	World.	Per cent. in U. S.
1889	21.6	70.9	30
1890	27.9	165.3	17
1891	68.2	233.4	29
1892	118.1	487.2	24
1893	154.4	716.0	22
1894	250.0	1,240.9	21
1895	417.3	1,418 2	29
1896	590.9	1,659.7	36
1897	1,214.4	3,394.4	53
1898	2,358.7	4,500.0 (est.)	52
1899	2,948.4	6,000.0 (est.)	49
1900	4,000.0 (est.)	7,500.0 (est.)	53

Those returns marked estimated (est.) are the best which can be conjectured from available data. It is expected that Canada will enter the list of producing countries this year, with a plant of 5,000 horsepower, and will add 1,000 tons each year to the world's output. Presuming that the total amount of aluminum produced in 1899 was used for the specific purpose of electric conductors, then the 6,000 tons of aluminum would displace 12,000 tons of copper, or a like amount of aluminum sheet would be equivalent to 20,000 tons of sheet copper, were the specification for culinary and cooking utensils. These comparative figures emphasize the important position that the metal has assumed. It may not be amiss to add here that the plants now producing aluminum are those of the Pittsburg Reduction Company, at New Kensington, Pa., and Niagara Falls, N. Y.; the British Aluminum Company, in Great Britain; the Aluminum Industrie Aktien-Gesellschaft, at Neuhausen, at the Falls of the Rhine, in Switzerland; the Société Electrometallurgique Française, at La Praz, and the Société Industrielle de l'Aluminum, at St. Michel, in France. There are also several large plants projected and in course of construction, notably upon the St. Lawrence river, in Canada, and at Rheinfelden and Salzburg, in Germany.—"Cassier's Magazine."

ALUMINUM CONDUCTORS FOR ELECTRIC TRANSMISSION.

The already practically foreshadowed widening use of aluminum conductors for electric-transmission purposes adds interest to Lord Kelvin's recently-expressed opinion of them. The weight of aluminum required, he said, is almost exactly one-half of the copper which would produce the same effect. The diameter of cable is 28 per cent. in excess of one made of copper, and the cost of insulation for an underground cable is increased in about the same proportion when we pass from copper to aluminum. Aluminum is not a pleasant metal to deal with, but its high conductivity will make it invaluable for overhead transmission. It is true also that the weight to be supported on posts is half of copper, but the surface exposed to the wind is greater, and its strength is not great. The chief drawback to its use, especially overhead, is its liability to become rotten. This defect does not exist if the metal be pure, and especially if free from sodium. But exposure to the atmosphere, especially near the sea, induces deterioration. The fact that aluminum is easily oxidized ought not to condemn it. The same is true of iron and steel, and yet we do not hesitate to place structures of these metals in exposed positions. A few hundred yards of $1\frac{1}{4}$-inch aluminum wire were put up by Lord Kelvin on a Scotch estate somewhat over a year ago, and on this line he is watching the effects of weather.—"Cassier's Magazine."

ALUMINUM IN THE FOUNDRY.

Hundreds of tons of aluminum are now consumed annually in metallurgy. Steel makers are well acquainted with the fact that ingots are very apt to turn out spongy at the top; and it has been the practice, when particularly good ingots are required, to cut off and remelt the faulty portion. By adding a few ounces of aluminum to the ton of molten steel, ingots of uniform solidity may be obtained. In the production of large castings the aluminum is added to the molten metal before pouring, but it is frequently found advantageous to insert small fragments in the mold at places where difficulties may be anticipated. Equally beneficial results may be secured by the addition of a small pro-

portion of the metal to iron or brass, either in the mold or in the ladle. The employment of aluminum in this manner causes the instant liberation of all gases contained in the metal, and prolongs the period of fluidity, thus permitting a longer time for the escape of the gases. In nearly all steel works, and in a large number of foundries, aluminum is extensively used, and we believe that the number of "wasters" is consequently reduced by more than 80 per cent. Another extremely serviceable manner in which aluminum may be employed is for pattern-making. The heavy brass gates of patterns may advantageously be replaced by aluminum, to which about 5 per cent. of copper and an equal proportion of zinc have been added with the object of increasing rigidity. Patterns of light weight naturally enable savings to be effected in different directions. The work of molding is facilitated, as the men expend less effort in dealing with dead weight; the patterns can be handled and stored more economically; and freight is considerably reduced, as aluminum is about one-third the weight of iron, and less than one-third that of brass. At a recent meeting of the Franklin Institute it was mentioned that a foundry at Philadelphia had some large iron castings to make for a cable tramway, the pieces being intended to extend the full width of the track, supporting the rails and carrying at the center the conduit for the cable. Wooden patterns were at first used, but considerable trouble was caused by wear and tear in the sand, as well as by warping and springing out of alignment. Finally patterns were made in aluminum, with the result that all trouble ceased, and most excellent castings were obtained. Large sums are spent on permanent iron patterns in various engineering industries, and the value of the metal is probably small as compared with the cost of preparation. In view of the savings to be effected in the molding shop, the general substitution of aluminum ought to be worthy of consideration.—"Fielden's Magazine."

WATERTOWN ARSENAL TESTS OF METALS.

The report for the fiscal year ending June 30, 1899, has recently been published by the Ordnance Department, United

States Army. This volume of 900 pages, and the nineteenth of the series, contains the results of tests of ordnance material and constructive material of a general and investigative character.

The ordnance tests represent material examined in the ordinary course of routine work on the properties of forged steel, steel castings and cast iron used in the fabrication of small arms, field, siege and seacoast guns and mortars, and for their carriages and mounts.

In the larger caliber guns the tensile properties of the tubes and jackets are as follows: Elastic limits from 45,000 to 55,000 pounds per square inch, tensile strength ranging from 85,000 to 95,000 pounds, with an elongation after fracture of 20 per cent. and contraction of area 40 per cent. or more, measured on a specimen 3 inches long.

For small arms, the barrel steels have an elastic limit generally above 70,000 pounds, with the tensile strength ranging from 110,000 to 120,000 pounds per square inch. The fractures of these specimens were commonly silky in appearance, developing good elongation and contraction of area. In this group of tests is found a special tungsten-steel, having an elastic limit of 101,000 pounds and tensile strength 125,500 pounds, the elongation being 19 per cent. and contraction of area 34 per cent. This steel contained 1.94 per cent. of tungsten and 0.72 carbon. Steel castings used in the mounts of 6-pounder and 15-pounder guns had a tensile strength of from 60,000 to 70,000 pounds.

Internal strains in gun forgings were investigated. The tubes of 5-inch rapid-fire guns were treated for the purpose of introducing strains in the metal in the following manner: The tubes were heated to a temperature of 800 to 975 degrees Fahrenheit, and then rapidly cooled by a stream of water passing through the bore. This treatment results in putting the metal in a state of compression at the bore, with the outside in a corresponding state of initial tension. The compressive stress at the bore in one case is reported as 40,000 pounds per square inch. Annealing relieves these initial strains, and exposure to a temperature of 1,000 degrees Fahrenheit reduced the value of the internal stress from 26,200 to 5,500 pounds per square inch. A

rearrangement of the internal strains occurred when the dimensions of the forging were changed, some of the metal being turned off.

Cartridge brass, in sheets about $\frac{1}{8}$ inch thickness, showed an elastic limit of 16,000 pounds, a tensile strength of 46,000 pounds, with the exceptional elongation of 60 per cent. on a 10-inch section. The composition of this metal was: copper, 70, zinc, 30.

Compression tests on mortar and concrete occupy 128 pages of the report. The mixtures ranged from a concrete consisting of 1 part neat cement and 2 parts broken stone to the lean mixture of 1 part cement, 6 sand and 12 stone. Different ages of setting were given the material. Mixtures were prepared in which there was a deficiency or excess of mortar with reference to the voids in the stone. There were mortars which were kept in a state of agitation for several hours after mixing and before being finally tamped into the molds and allowed to finish their setting without being further disturbed.

The strongest concrete tested was the neat cement and broken stone mixture, with no sand present, the strength diminishing as the leaner mixtures were reached. At the end of six months the strength of the several mixtures, 1:0:2, 1:2:4, 1:3:6 and 1:6:12 stood to each other as 100, 68, 57, 25, in the case of some concretes made of Alsen's Portland cement. The crushing strength of the 1:0:2 mixture was 5,330 pounds per square inch.

Concrete cubes loaded on a part of the surface, taken equidistant from each edge, showed higher strength per square inch on this reduced section than displayed by a corresponding cube loaded over the entire surface. A cube loaded over two-thirds of the end surface showed a crushing strength of 6,651 pounds per square inch. Making a comparison of surfaces differing in extent, the greater strength was shown by the specimen loaded on the smaller area, pressures per square inch being considered as before.

The elastic properties of mortars and concretes were also investigated. The compressibility was observed as the loads were

applied and the resilience determined as they were released. The values of the moduli of elasticity ranged from 1,500,000 to 3,500,000 pounds per square inch, occasional results being found outside of these limits. Cubes of the greatest strength were the most rigid under load.

On the effect of retarded setting, a mortar composed of one part Portland cement, two parts sand, mixed and immediately put into the molds, had a crushing strength of 2,750 pounds, whereas the same mortar kept in a state of agitation for a period of five and one-half hours before putting into the molds had a strength of 2,245 pounds, showing a loss of 18.4 per cent. The specimens were 62 days old at the time of testing.

Portland cements, neat, were shown to acquire a decided rise of temperature when made into large cubes, reaching this higher temperature a number of hours after mixing. Thus the temperature of a 12-inch cube mixed with 17 per cent. of water rose to 200 degrees Fahrenheit nine and one-half hours after mixing. During the first five hours the temperature rose slowly, after which the rise was more rapid until the maximum was reached, followed by a slow fall until the temperature of the room was reached. When more water was used in mixing there was a slower approach to the crest and the maximum was somewhat lowered. Smaller cubes were less affected, a 6-inch cube only reaching 90 degrees, the initial temperature being 72 degrees Fahrenheit.

Referring to the test by repeated stresses, the report states that interest centers on the endurance of steels subjected to a maximum fiber stress in the vicinity of 40,000 pounds per square inch, earlier tests having shown that many steels of high tensile properties were unable to endure repeated stresses of this magnitude without early rupture. A test is now given in which a bar of 0.82 carbon-steel has endured 65,000,000 repetitions of 40,000 pounds per square inch, alternate tension and compression, without rupture. The test was made on a shaft loaded transversely, the outside fibers of which were subjected to the load mentioned.

Tests by impact are reported on soft metals, lead, tin, zinc and

copper. Lead was regarded as peculiarly well adapted for preliminary tests of this class. Owing to its low elastic limit and great malleability the permanent deformation of the metal can be taken as an index of the effect of impact. The experiments showed increased resistance to flow of the metal as the striking velocities of the ram increased. The cumulative effect of a number of short blows was greater than the effect of a single blow from a height equal to the aggregate of the short blows. Eighteen blows of a ram from a height of 2 inches each caused the same permanent deformation to a lead cylinder as one blow of the same ram from a height of 56 inches.

The results on lead were influenced by the crystalline structure of the metal. Samples from the pig, compressed in a direction normal to the axes of the crystals, flowed most in the direction of their length. A cylindrical specimen, originally 1 inch diameter, assumed after impact an elliptical shape in cross section, measuring 2.09 inches diameter lengthwise the crystals, but expanded only to 1.07 inches in a crosswise direction.

Additional upsetting of the lead after a period of rest developed the remarkable tendency of the metal to renew flow in the opposite or crosswise direction as the principal direction of radial movement. There was further shown an appreciable gain in rigidity against flow, the result of a succession of blows of the ram, and from which the lead recovered during an interval of rest.

Tin and zinc flowed most in the crosswise direction, but with a less pronounced difference in rate than displayed by the lead.

TWO IMMENSE FLOATING DOCKS.

Mr. Joseph Beale, of Washington, D. C., agent in the United States for Clark & Standfield, dock engineers of London, England, favors the "Review" with particulars of a floating dock for Bermuda, for which the British admiralty a short time ago accepted the tender of Messrs. Swan & Hunter, of Wallsend-on-Tyne. Mr. Beale also sends data comparing the Bermuda dock with the dock which is being built at Sparrow Point, Md., for the

United States government, and which is to be located at Algiers, La. Messrs. Clark & Standfield are the designers of both docks. The Bermuda dock is to be finished in twelve months, tested and then towed to her destination. These two docks are similar in most respects, the main difference being in the manner of shoring the ships on the dock. The American plan is to depend upon keel blocks in conjunction with docking keels; the English plan is to support the armor belt on a large number of more or less vertical shores inserted under an angle iron firmly attached to the belt. The following data is given by way of comparison:

	Bermuda Dock.	Algiers Dock.
Type	Self docking.	Self docking.
Material	Steel.	Steel.
Length over keel blocks, feet	545	525
Width of entrance, feet	100	100
Depth on sills, feet	33	28
Height of keel blocks, feet	4	4
Depth of pontoon, feet	15¾	17½
Weight of hull, tons	6,500	5,850
Maximum power, tons	17,500	20,000
Cost	$900,000	$810,000

—"Marine Review."

THE LARGEST DOCK IN THE WORLD.

Liverpool's importance as a great sea port has been considerably increased during the last two years by the opening of the new "Canada" graving (dry) dock, a part of the general system of improvements upon which operations were commenced some years ago, and upon which about $25,000,000 are to be expended. This is the largest dock in the world. Its length is 925 feet 6 inches; width at entrance, 94 feet; width of top, 124 feet 2 inches; width of bottom, 94 feet; depth on sill and blocks at high water of ordinary spring tides, 32 feet. The main body of the dock and the entrance are constructed of Portland cement concrete, 8 to 1, finished with concrete 6 to 1. The dock is filled by two rectangular culverts, one on each side of the entrance, each 8 feet high and 6 feet wide, closed by valves or cloughs of greenheart wood, worked by hydraulic power, with stand-by or

emergency cloughs worked by hand power. The dock is emptied by means of three centrifugal pumps, each having a suction pipe 51 inches in diameter. These pumps will, if required, empty the dock when filled to high-water level of ordinary spring tides (representing a volume of water of about 3,500,000 cubic feet) in an hour and a half. There is also one small pump 14 inches in diameter for dealing with leakage. The gates are opened and closed by means of hydraulic cylinders with multiplying sheaves and chains.

The Dock Board is having under construction a still larger dry dock of the following dimensions: Length, 1,000 feet; width of entrance, 95 feet; depth of sill at high water of ordinary spring tides, 37 feet. Improvements are also under way by which the depth of water over the sill of the "Canada" dry dock can be made anything desired.—"Marine Record."

USE OF CELLULOSE ON WARSHIPS.

The cellulose cofferdam belt, as protection to stability, is now a permanent fixture in American warship construction. Every battleship built in the past five years carries a 3-foot belt of corn-pith cellulose, packed to a density of about 8 pounds to the cubic foot and worked along both sides, above the protective deck, for the entire length of a ship. The battleships *Kearsarge* and *Kentucky*, which were recently turned over to the Government by the Newport News Ship Building & Dry Dock Co., were supplied with the protective belt of corn pith, and so are all the battleships now building.

The six new armored cruisers and five new battleships, for which the awards have just been made, will be supplied with belts of this specially-prepared cellulose, 3 feet wide. In the plans for these ships, and also for the three new protective cruisers for which bids will be opened February 1, provision was made for the corn-pith belt, and unless some invention or discovery of the future better serves the same purpose this waste farm product will be utilized, probably, forever. Curiously enough, the material for this improvement in the construction

of warships of the heavier class comes, not from the seaboard products, but from the waste of western farms. Its value lies in the fact that it will prevent a vessel's fighting ability from being destroyed even after she has been pierced in a dozen places. The value of some light substance to preserve the stability of armored vessels by displacing water that might enter a projectile had been appreciated by the constructors of the Navy ever since Uncle Sam commenced to build steel armored ships. The French, to meet this requirement, originated the use of cellulose, which, when fired into and pierced, swells up under the influence of the water with which it comes in contact and makes further inflow impossible. It was adopted in the American Navy after several trials, but the cellulose we use to-day in our ships is not manufactured from the same material which the French used.

Our cruisers were the first to be supplied with the simple cellulose belt. The *Columbia*, *New York* and *Olympia* have protective decks of ample strength to keep out the shells of vessels they are liable to engage, while their stability is further protected by belts of the cellulose along the edges. Of course, improvements are being made all the time and the cellulose belts in the new battleships and cruisers will represent the very latest American ideas in the development of this important feature of warship construction.

No thoroughly satisfactory cellulose material for this purpose was discovered, however, until the pith of cornstalks was utilized in its manufacture. The only perfect obturator found thus far is corn pith. It will absolutely prevent the inflow of water through an opening made by an 8-inch shell. It is thoroughly fireproof, when chemically treated, and meets the requirements of the situation in every way. Maize, or Indian corn, is exclusively an American product, this giving us an advantage over all nations. In the western fields this country has the best material in the world for imparting this sort of strength to warships. For keeping out water a cellulose belt of three feet, the uniform width in our Navy, may be said to be as efficient as a 6-inch belt of steel, so that the stability of our warships can

be protected, when there is back of it a good protective deck to save the vitals 100 tons of corn pith of cellulose where 1,000 tons of steel would be required. In vessels of high speed, where weight is needed for machinery and the armor belt cannot be carried, cellulose is used to preserve the stability. In battleships thick armor is used amidships and a protective deck and cellulose belt beyond the limits of this armor.

The use of corn pith for this purpose was first suggested by Prof. Mark W. Marsden, who had observed its remarkable absorbent qualities. He brought the matter to the attention of the Cramps, and at their suggestion, he devised an apparatus for separating the pith from the stalk.

In 1895, the naval authorities, after discussing the matter, were induced to make a test of the new process. A 250-pound projectile was fired through a steel cofferdam packed with cellulose 3 feet thick. A hole a foot in diameter was made in the structure. Water was immediately turned on and continued for an hour, at the end of which time not a drop had gone through. The packing at the hole in the rear of the plate was not even dampened. The cocoa cellulose, tested at the same time, failed to meet these requirements. Since then the use of corn pith has been adopted in the U. S. Navy.

The cellulose is packed in the cofferdam space on a warship between the outer and inner walls. A belt of this material 3 feet thick backs up the armor belt, which extends 6 feet above the water line and about the same distance below, running entirely around the vessel, but tapering in thickness at the ends. Fifty tons of cellulose, in its final state, are required to equip a vessel like the battleship *Illinois*, which is soon to have her trial trip, and this is computed to equal 500 tons of steel in adding to the defensive strength of the ship. About 15 tons of raw material are required to produce one ton of cellulose. To supply this important feature in the construction of each of the new 15,000-ton battleships, therefore, will require more than 1,000 tons of stalks, or the product of more than 300 acres of corn land. Just as corn pith enables the fighting ships to keep afloat, even after holes have been punched in their sides, it may be

utilized to add to the safety of passengers and freight ships. The Marsden Cellulose Company recently contemplated establishing one of their plants at Newport News, with the idea of filling from it the orders of the Newport News Ship Building and Dry Dock Company for the material it uses on warships built at Newport News, but negotiations did not turn out as expected, and the company built a plant at West Point, on the York river.—"Marine Review."

MANUFACTURE OF CELLULOSE.

"The Tradesman," a southern publication, contains an article in a recent issue upon the use of cellulose in warships and its manufacture. It is written by Mr. T. S. Ayers, superintendent of the Marsden plant at Owensboro, Ky. As an industry the manufacture of cellulose is comparatively unknown. Cellulose is the pith from the mature and well seasoned cornstalks, with the fiber extracted, so it may readily be seen that to do this on a commercial scale would involve the expenditure of large sums of money for the necessary large factory buildings with the complicated machinery to make the separation of pith from the mass of leaves, shucks, shell-joints and fiber. As an industry it created something of value from waste cornstalks and added a manufacturing business that was not competitive, as it did not force any other article aside by its coming into use. To the farmer it has added a value from $5 to $8 to his corn crop—not a net value, but an amount which he may realize positively for his labor and at times when he would otherwise be unemployed, with the chances that his net profit will be more than that which he derives from his corn. Wherever a factory is located it raises the value of corn land within a distance of ten miles. After the factory is built a buyer is sent out, about August 1, among the farmers to make contracts for the season's supply of stalks, and so far the supply has not equaled the demand. Yet this year in Mr. Ayers' locality over 20,000 acres have been contracted for, and this should yield the farmer a minimum of $100,000 and it may reach as high as $160,000. In addition to this, the labor for handling and stack-

ing would cost about $10,000, for it is not in condition to use before the following spring. These stacks, or ricks, are built about 30 feet wide, and 35 feet high, with lengths from 300 to 1,000 feet long, and average, when properly built, about two tons per running foot. The removal of material begins on December 1, continues until the following spring, the only condition being that it shall be in proper shape and free from dirt or moisture.

The first step in the course of manufacturing is to place the bundles of stalks on a long conveyor, which carries them to a heavy cane cutter, where they are cut into ½-inch lengths. From there the material goes to a series of reels, where it is divided into three streams, the larger leaf and shuck in one, small pieces of leaf, shuck and shell in another, the pith in its first stage of separation in the other. The larger leaf and shuck is baled and sold as cattle fodder, or the shuck, after being separated and with some additional preparation, is sold to the mattress maker. The fine pieces of leaf, shuck and shell goes to the main mill, where it is ground into a fine meal for cattle feed. The pith goes to separators, which extract all the remaining leaf, shuck and shell it is possible to get before being ground. The government regulations call for uniform sizes, and after being ground the final separation is made. This part is most difficult to do, as there are the small pieces of leaf, shuck and fiber which have about the same specific gravity as pith, and then the pieces of joints and shells, the same size as the cellulose, yet far heavier. This part is finished on a series of ingenious machines, and when it drops into the bag finished and ready for chemical treatment and pressing, it has not been touched since as raw stalks it was placed in the conveyor traveling over a half mile on belts and conveyors, through pipes and up elevators. The next step is to treat it chemically so as to make it fireproof, as each batch of 200 pounds is tested by a government inspector with a red-hot bar of iron to see if it is proof against burning, and should it flame it is rejected.

After being fireproofed it is then dropped into a 100-ton hydraulic press, which presses thirty-six cakes of cellulose at a time. There are thirty-six tubes in the case, each tube being 6

by 6 by 24 inches, and these are filled with loose cellulose, then pressed down to about five inches, and after being taken out of the press raised slightly so that it forms a 6-inch cube. In this shape they are placed in the cofferdams of war vessels. These cakes are placed into cardboard cartons, and 140 of them are packed in a box lined with waterproof paper, and after being packed the government inspector affixes his stamp on the box, showing when it was passed and approved by him. It is then ready for the United States government.

As to its uses, and the conditions which have led up to it, we would have to go back to the European navies, as they were early experimenters in trying to obtain a perfect water excluder for their vessels when pierced by the enemy's shot. Yet it must be confessed that, abroad, their tests were unsatisfactory and often blank failures. The failure was probably due in a measure to the inferior quality of material used, and to its lack of proper treatment for preservation and non-combustion. The faults developed on trial seem to have been inflammability from small explosion, and decomposition and loss of saturating qualities when exposed to moisture. The odor from decaying material was also objectionable.

The Italian navy tried a species of cat tail, but discarded it because of its high cost and bad keeping qualities. The cat tail as used consisted of the furry heads packed in canvas bags and covered with some non-inflammable coating. After that Italy tried a mixture of cork shavings and tar pressed into cakes. France also experimented with the cat tail and various other material, but finally settled on zostive, a sea weed common to the French coast. The sea weed is dried, treated chemically, packed in canvas bags and smeared with a water proof coating. For stowage in cofferdams the zostive is pressed into bricks, and being a marine growth it is safe from deterioration in salt water. In Germany the favored obturating material is cork cut into smooth slabs about an inch thick and closely stowed in the cofferdams with marine glue to fill the interstices. The other powers have made experiments, but came to no definite conclusions as to the relative value of different material.—"Marine Journal."

BILGE KEELS ON TORPEDO BOATS.

Experiments are to be carried out at Portsmouth to determine whether, and if so to what extent, bilge keels would affect the speed and maneuvering power of torpedo-boat destroyers. A 30-knot vessel is to be selected, and she is to have her decks cleared of torpedo tubes and other obstructions in order to provide room for 50 men in addition to the crew. The boat is to be run without bilge keels at 15, 20 and 25 knots, and the men are to be so distributed as to produce the maximum of heel consistent with safety while the vessel is under way. The boat is then to be docked and provided with bilge keels, after which precisely the same trials are to be gone through. If it be found that there is no material depreciation of speed and maneuvering power, bilge keels will be supplied to all the destroyers, with a view to improving the steadiness of their gun platforms.

HEIGHT OF OCEAN WAVES.

A very interesting series of wave studies from the pen of Mr. Vaughan Cornish is now appearing in the columns of "Knowledge," in the January issue of which the size of waves is dealt with. In the course of this article Mr. Cornish says that it was in the Southern Indian Ocean, between the Cape of Good Hope and the isles of St. Paul and Amsterdam, in the region of almost continual westerly winds, that the largest waves were observed. On October 25, 1867, during a gale from the northwest, with violent snow squalls, 30 waves were measured at different times of the day which averaged 29.53 feet (9 meters) in height. The largest of them were 37.53 feet (11 meters) in height, and of these no fewer than six in succession were observed, which followed one another with admirable regularity. They lifted the corvette as if it had been a whaleboat, then left her wallowing in a deep trough, extending far on either hand.

Lieutenant Paris, who made these observations, had to mount to the twenty-second rung of the shrouds before he attained the level of the crest. On the evening of the same day waves

even larger were seen but not measured. Those on board the corvette seem to have agreed that the waves of this October 25 were the largest within their experience. The height of the individual waves was often found to vary in the proportion of 1 to 2; it was only in very favorable conditions that the average height was 0.7 or 0.8 of the extreme height. In the open ocean a strong wind soon caused waves of as much as 10.4 feet (3 meters).

The distance from crest to crest was found often to vary in the proportion of 1 to 3 in two successive waves. In a rising sea the wave length increased more rapidly than the height, a process which was found to continue for several days. Thus, to the east of the Cape of Good Hope, during strong west winds, which blew with great regularity for four days, the height of the waves only increased from 19.69 to 22.97 feet (6 to 7 meters), while the length, which was but 370.74 feet (113 meters), on the first day, had attained 771 feet (235 meters) on the fourth. This was the greatest daily average length observed, but individual cases occurred in which more than 1,312 feet (400 meters) separated two succeeding ridges, and an interval of 984 feet (300 meters) was not uncommon.

ECONOMIZERS IN THE RUSSIAN NAVY.

Economizers, it appears, are becoming quite out of favor in the Russian navy, as they accumulate on their surface so much soot, which, being a bad conductor of heat, diminishes the steam-producing qualities of the boilers. To clean this away takes up too much time and trouble, and puts the ship out of line for too long. Moreover, it goes hand in hand with the diminution of the general heating area of the boilers with relation to the number of square feet that go to each I.H.P. After a searching examination from all points of view into the good and bad sides of fitting economizers, the question has been decided in the direction of their disadvantageousness, and accordingly none will be fitted in ships for the future.—"Journal Royal United Service Institution."

A NEW SYSTEM OF WELDING.

The system recently developed by Dr. Hans Goldschmidt, Germany, for obtaining high temperature by a chemical reaction, equaling or exceeding the temperature of the electric arc, is of quite as much interest to the mechanical engineer as to the chemist. Aluminum and oxygen have a strong affinity for each other, and when these two elements are brought together under favorable conditions a vigorous reaction takes place, resulting in temperatures of over 5,000 degrees Fahrenheit. There have been obstacles in the way of applying this process to any practical work, mainly because of the difficulty in getting the reaction started and of its extreme rapidity when once under way. Dr. Goldschmidt, however, has succeeded in overcoming both these difficulties. He uses powdered aluminum and a metallic oxide, the latter supplying the oxygen. These elements require a high initial temperature to bring about a reaction, but he discovered that by mixing with these a quantity of the chemical, barium superoxide, ignition could easily be started. This having been accomplished, he found that the combustion could be regulated by the manner in which the powder was added. This, in brief, is a statement of what has been accomplished chemically, but of more interest to those engaged in mechanical work are the results that have been attained through this discovery.

In a late number of "Fielden's Magazine" is a fully illustrated article describing some of the applications that have already been made in Germany, and to this article we are indebted for the brief description which follows. An important application of the process is found in metallurgy in the reduction of metals, but its chief use will evidently be for welding together lengths of wrought-iron pipe of various sizes, for welding rails and for repairing faulty steel castings, etc. The heating agent or powder has been patented and is known as "Thermit." The process of welding pipe consists in clamping together the two ends and then casting on the joint in order to bring the iron up to a welding heat. The increase in temperature causes the pipes to expand, but they are prevented from doing so longitudinally by the clamps. The expansion, therefore, taking place within a

restricted area, acts as a welding force upon the pipe faces, pressing the hot iron together. For the whole operation there is required only a slag-lined fire-clay crucible, a pair of tongs, a clamp, a box of Thermit and some matches. Before the molten Thermit is applied the joint is surrounded with a mold of sheet iron, backed up with sand or clay, which acts as a receptacle for the Thermit when it is poured. The requisite welding heat is imparted to the pipe in a very short time, and after the joint has been allowed to cool the solidified Thermit can be knocked off with a few blows from the hammer, leaving the pipe clean and smooth at the joint. A peculiar property of the Thermit appears to be that it does not attach itself permanently to the pipe or other metal being welded, as might be expected.

The same process is used in welding rails, and in a number of instances where the experiment has been tried the welds have been found quite as satisfactory as the usual fishplate joint, besides being nearly if not quite as cheap, and in the case of electric roads affording better conduction of the current.

In repairing steel castings having imperfections, the Thermit is allowed to run into the blowhole where it remains firmly attached, owing to the irregularities of the surface. A remarkable and somewhat startling result that has been obtained in the application of this compound is in softening and even penetrating armor plate or plates used for safes or vaults. A nickel-steel plate about 1¼ inches thick was easily penetrated in a short time by the application of molten Thermit, and a hole of any dimension could be made through such a plate by simply pouring the Thermit so as to follow a circular line enclosing what was to be the hole. An exceedingly valuable application of the compound appears to be that the welds stand well under test. Pipes which have been welded can be bent to almost any angle without disturbing the welded connection, and it is also believed that the process can be applied as cheaply as can flanged joints. The main difficulty in welding pipes is that one would be unable to remove a length which, however, in many instances where piping is expected to be permanent, would be of no particular disadvantage.—"Machinery."

THE BURNING OR MENDING OF CASTINGS.

[By Edward B. Gilmore, Milwaukee, Wis., in "Proceedings of the American Foundrymen's Association."]

It has often been questioned whether it is advisable to burn castings which are broken or have proved defective, even after a great deal of expense has been put upon them, and when one begins to theorize upon the matter, the natural conclusion derived is that it is impossible to mend a casting by burning. When we get to practice, however, we find that the reverse is the case, and I have burned castings which were considered by many founders to be hopeless. For instance, in making a marine-engine cylinder, a piece was broken from a sharp point of the exhaust core which the coremakers had not secured fast enough, and this caused a hole to be left clear through to the outside of the casting.

The procedure that we adopted was based upon the laws which govern expansion and contraction as nearly as possible. We put the casting upon a car with the defective side uppermost, and made loam molds to cover this, also a loam mold to fit the inside of the casting at the same place. Then we took off the molds, dressed them up and gave them a coat of blacking, dried them thoroughly, put them back to their places, and secured them tightly to the casting. We then made a runner to take off the metal poured upon the casting, the overflow of which was caught in another ladle placed for the purpose. After all the arrangements had been completed the whole thing was put into the oven, which is a very important matter, as you must get the casting as well warmed as possible, for this is where the success or failure in burning comes in.

It is essential to have a casting to be treated in this way heated up to at least 600 degrees Fahrenheit, and this can easily be accomplished. After an oven is thoroughly heated with the usual coke fire, about one hour and one-half before you have the metal ready for burning, fill the fire in the oven with soft wood, and continue doing so until ready. This will raise the temperature to the desired point. In order to assure yourself that the oven is hot enough, you can put a piece of lead upon

the car; if it melts you may be certain that you have the temperature high enough, lead melting at 612 degrees Fahrenheit. You could also place a piece of tin on the car, as it melts at 412 degrees, and by doing you will be able to determine very nearly to what temperature your oven has been heated. When everything was ready, in the case under discussion, the car was pulled out of the oven. The metal, good and hot, was poured into the mold prepared upon the casting, enough being used to melt the casting about 1 inch on either side of the defective part. Dry charcoal blacking was used to cover the cast, and then the whole thing was run back into the oven and let cool gradually.

I have now burned a number of large castings on this principle, and have been successful in every instance. The iron used for this purpose should be of the very softest nature, so as to keep down the shrinkage, and make it easy for machining and chipping.

There are many castings which can be easily burned without being brought up to this excessive heat, such as when you have to mend on some extreme point, where undue expansion and contraction will not matter. We once had occasion to burn the casing of a centrifugal pump which got broken right across the casting. This was burned very successfully without preliminary heating, but even in this case it would have been advisable to heat the casting, as it would have facilitated the running of the metal. I have seen castings of this description burned cold, and as soon as the metal touched the cold iron it was chilled, and the consequence was a failure.

Some founders in burning castings make a practice of bringing the metal forward in small ladles, with the idea of bringing it very hot in this way. This is a mistake, as you can put it all into one ladle, and by having a large quantity it will hold its high temperature for a longer period. When you pour you can maintain a good, steady stream upon the part, besides reducing the extra expense of additional help in handling so many ladles.

In burning the necks on rolls, it is much better to adopt the principle of making a loam mold, leaving a hole at the bottom so as to run off the metal until the roll is melted. After the

mold is prepared, finish and dry it, then secure it to the casting and build a good, hot fire around the casting at the part to be repaired until it is a bright red. Now pour very hot iron into the mold and allow it to flow off until the casting is melted. This can easily be determined by trying it with a feeling rod, and when satisfied stop the exit of the metal and fill the mold to the required height. You can also burn a steel face on to a hammer die on the same principle, but it is not necessary to heat the steel, as the iron melts it very rapidly.

The question is very often asked, "Is the casting as strong after being burned as it was previous to being broken?" In a great many instances it is stronger, as very often there is a contraction strain upon the casting which has been relieved by the breaking, and when properly mended it should be certainly as strong.

SMOOTH-ON IRON CEMENTS.

The Smooth-On Iron Cements are used for so many purposes that it will be interesting to the public to know about them and some of their uses. These cements are prepared in powdered form and packed in one, five and twenty-five pound tins, in which they can be shipped to any place, however remote, as the cements keep unimpaired indefinitely in any climate. The Smooth-On Iron Cements No. 1 and No. 2 are made especially for and used by marine and stationary engineers, No. 1 for repairing leaks or making connections in steam or hydraulic work, applied with a trowel, and No. 2, for coating the inside seams and rivets of leaky steam boilers, can be applied with a brush. To apply these cements they are mixed with water according to the directions on each can, and in a short time the material hardens, becoming solid iron. During the process of hardening the cement expands slightly, and by this action it becomes very valuable for many mechanical uses, many repair jobs being made possible that could not have been accomplished without Smooth-On. When hard, Smooth-On is insoluble in water, steam or oil, and will withstand a red heat; its conductivity is the same as iron.—"Marine Journal."

THE BURTON PLASTIC PRESSURE TUBE EXPANDER.

At the Thornycroft works a new tool for expanding boiler tubes has been successfully used, which may supersede the old taper mandrel and rollers. It is a well-known principle that certain metals, such as lead, can be made to flow when subjected to pressure; and upon this principle the operation of the invention depends. The tool consists of a phosphor-bronze cylinder containing a piston provided with three piston rods which pass through the cylinder cover and are secured to a bearing block. The rear end of the cylinder is fitted with a valve. At the forward end of the cylinder, in the center of the cover is a mandrel, enlarged at its forward end to fit the boiler tube.

The piston having been drawn back to the rear end of the cylinder, a lead bush is placed around the mandrel. After the mandrel has been forced as far as possible into the tube, the bush will fill the space between the tube and the mandrel. Water under high pressure, when admitted to the cylinders, will draw the mandrel back, whereby the lead bush will first be wedged into the space between the tube and the mandrel and will then flow past the shoulder of the mandrel. Simultaneously the tube will be expanded. Finally, when the mandrel shoulder enters the tube plate, the lead is thrust between the face of the bearing block and the end of the tube. The mandrel can be easily taken out of the tube and the thin sheet of lead still remaining scraped off. The amount of expansion can be regulated by varying the length of the bushing. Tubes can be readily expanded into flanges for steam pipes and into tube-plates. The tool is the invention of Dr. C. V. Burton, of London, England.—"Scientific American."

PURE WATER FOR ICE MAKING.

The process of evaporating sea water to be used in the steam boilers of a vessel at sea has been in operation for a long time, in consequence of the necessity for preventing the deposit of salts on the heating surfaces when the pressures to be carried by

these surfaces are high. On the Red Sea littoral, Mombasa, and places where pure water for drinking purposes is scarce, this method has been applied to purify the water before drinking. The evaporation of water and its redistillation was always found necessary when it was required pure for chemical purposes, and now the uses to which ice is put necessitate that the water from which it is made should be purified also.

Of course, natural ice, such as that obtained from the deep and little-disturbed lakes of Norway, possesses almost all the qualifications necessary for the table; but ice obtained from shallow, unprotected lakes which have strong currents running through them, and in which mud rises from the bottom and remains in suspension, is a commodity of quite another character, and to prevent the user being provided with ice of that nature it is necessary to adopt methods which will prevent water of inferior quality being used for the production of artificial ice. When, therefore, it is desired to make artificial ice, it must be an advantage to have the simplest and cheapest methods in operation for purifying the water from which it is made.

The simplest method of producing pure water is to evaporate it, and then condense it, but this is rather expensive. In the British Navy it is usual to use a compound evaporator, and in some streamers tri compound evaporators, which result in greater economy. In some places on land the compounding has gone on until a sextuple effect is produced. The average consumption of steam to produce water by the different stages of compounding are shown in the following table:

Compound	1	pound of	steam	produces	1½	pounds	water.
Triple	1	"	"	"	2½	"	"
Quadruple	1	"	"	"	3	"	"
Quintuple	1	"	"	"	3¾	"	"
Sextuple	1	"	"	"	4½	"	"

In these higher stages of compounding pressures of steam up to 40 pounds or so must be used. With an average working boiler an evaporation of 9 pounds of steam should be obtained per pound of coal, and when this is the case the quantity of water

evaporated per pound of coal will be 40½ pounds. This is not an excessive price in fuel to pay for pure water.

In towns like London and New York there is a commercial value placed on "ice made from pure distilled water," and users are willing to pay for the superior article. The rough, semi-opaque ice often given is not in so great requisition as clear pool ice. There is also the further advantage that water out of a well sunk in the factory can be used directly after going through the evaporators, and the first cost of water which has to be paid for is saved. As towns' water costs about 6 cents per 1,000 gallons, the saving of its cost by purifying the water brought from the ice factory's own well will go a long way towards reducing the expense of purification.—"Fielden's Magazine."

THE PERMANENCE OF IRON AND STEEL STRUCTURES.

The limit of endurance of iron or steel structures subject to the ordinary vicissitudes of atmospheric exposure, either directly or indirectly, still remains to be determined. Some elements of the question, however, are gradually being brought into definite shape as engineering experience is extended. It was not very long ago that some civil engineers, even, entertained apprehensions as to the endurance of iron members subjected to indefinitely extended applications of loads producing stresses below the elastic limit, and that apprehension still exists in many lay minds. The investigations of Wöhler, Spangenberg and others in the field of fatigue of metal show that iron or steel may be subjected to the usual working stresses employed in reputable structural design for an indefinitely great number of times without any discoverable deterioration. Metallic structures, therefore, may be confidently counted on to sustain any duty whatever, within limits of first-class design for any period of time without fatigue or other deteriorating influence, provided corrosion be prevented. This latter agency, however, is the active enemy of the life of iron or steel structures, and it is in the prevention of oxidation that engineers must make their investigations in order to secure practically indefinite length of life.

It is well known that painting with any one of a number of good paints constitutes a perfect protection for all accessible surfaces. The difficulty in preserving accessible surfaces of iron and steel against corrosion arises from the fact that the paint itself needs frequent renewal; a renewal at such comparatively short intervals, in fact, that injurious neglect frequently exists. If such observations can be made in regard to accessible surfaces, every engineer knows that those surfaces of iron and steel members which are not accessible are subjected to far more acute conditions. There are many points of inaccessibility, such as those at the lower chord panel points of an ordinary pin bridge, where moisture continually accumulates and where more or less corrosion must always be found. This corrosion may be small in amount or be proceeding at an extremely slow rate, but so long as it exists the life of the metallic members which afford the field of action must be considered of limited duration and nothing short of complete cessation of corrosion and continued immunity from it will afford true permanence to the structure.

The serious rusting occurs after the shop coats and the first field painting have been satisfactorily completed. In other words, it takes place after the most complete protection possible has been given to metal by the initial painting. It is believed therefore that engineering experience so far indicates not only that iron and steel structures must be carefully maintained by repainting accessible surfaces, but also that under many circumstances it is desirable to create conditions of such permanent protection that renewal of the protecting agent may not be necessary. For the ordinary bridge structure it is obvious that repainting is the only practicable means of satisfactory protection now at the command of the engineer, but wherever it is feasible to embed the iron or steel in Portland cement mortar or concrete, experience has shown that a truly permanent protection is afforded.

This is an interesting as well as important fact, especially in view of the wide range of application of combined concrete and steel structures already attained. It is clear that in this form of protection the steel member must not be covered with so thin a

shell of mortar or concrete as to permit the latter to crack, and that that design is most advisable which places no steel below permanent water elevation. This is not saying that iron or steel may not be so protected as to be safe against corrosion when properly embedded in concrete below water, but that under our present experience it is better to place the metal above that elevation. Wherever iron or steel has been well embedded in a Portland cement matrix, the results of such subsequent examinations as have thus far been made show that perfect protection has been secured, so that indefinite permanence or durability has been secured for the metal. This is probably due to the fact that in the process of setting all the moisture of the mass is required for crystallization, and that this consumption of moisture continues over the long period of time required for the ultimate hardening of the mortar or concrete. The condition in which the iron or steel is found in a properly designed concrete-steel structure is thus seen to be essentially equivalent to that of perfectly dry air in which no corrosion is possible. These latter conclusions are strengthened by some very interesting investigations by Mr. Carl Hambuechen, of the University of Wisconsin. and published in a bulletin of that institution for July, 1900. He takes the view that corrosion is in all cases probably an electrolytic action, and there is much evidence in favor of that view. However that may be, his work shows that the conditions requisite for corrosion are those which are absent in a concrete-steel combination, and it aids largely in explaining why the mortar and concrete matrix is such an effective and permanent preservative of iron and steel.—"Engineering Record."

SUBMARINE SIGNALING.

[By Arthur J. Mundy, in the "Scientific American."]

When the idea of a submerged signal first occurred to the writer he foresaw that he would be unable to develop it properly without the assistance of some master mind accustomed to wrestle with nature for her secrets. He therefore invited his friend, the late Prof. Elisha Gray, of telephone fame, to join him

in the undertaking, and received in reply an enthusiastic acceptance. Prof. Gray brought to the subject a wide knowledge of the laws of acoustics in their relation to electrical science, which has enabled him to overcome difficulties that have heretofore seemed insuperable.

An experimental boat, christened the *Sea Bell*, was built and equipped with an 800-pound bell to be operated electrically, the necessary power being supplied by a small dynamo driven by a gasoline engine. This bell is lowered into the sea through a well hole directly in the center of the boat until it is twenty feet below the surface. By an ingenious mechanism it may be either tolled continuously or made to ring any desired number or numbers, at the will of the operator, who is thereby enabled to send intelligible messages, each letter of the alphabet being represented by a given number.

The sound thus produced under water may be heard from a passing ship at a distance of, say, a mile or more, provided the observer go below in the hold of the vessel as close to the keel as possible and listen, just as he would listen for an air signal on deck. The sound waves produced by the bell come through the water and penetrate the skin of the ship, diffusing themselves in the atmosphere of the hold, where they are recognized by the unaided ear, just as any local sound might be. The sound is heard more plainly, however, by placing one end of a wooden rod against the skin of the ship and pressing the other end against the outer ear.

A common tin ear trumpet, such as is used by a deaf person, screwed into the end of a piece of gas pipe and submerged a few feet, the mouth of the trumpet being sealed with a tin diaphragm, will enable the observer at the upper end of the pipe to hear the bell a distance of three miles.

For greater distances Prof. Gray invented an electrical sound receiver. From this submerged instrument a connection is made to any part of the ship—say, the pilot house—where the navigator will listen for the sound through an ordinary telephone receiver.

A practical test of this apparatus was made on the last day of

the century just ended. Several gentlemen were invited to witness the results accomplished. Among those present were Mr. Henry M. Whitney, who has given the enterprize his hearty support from the start; Prof. Wallace C. Sabine, of Harvard, an expert in acoustics; and Commander Arthur P. Nazro, U. S. N., light-house inspector. The *Sea Bell* was anchored in the open sea off Winthrop Head, near Boston Light, and the steamer having the party on board proceeded seaward. These gentlemen testified to having heard the submerged bell.

At 1½ miles the sound of the bell was very loud and very distinct; at 4 miles the sound was quite as distinct and almost as loud as at 1½ miles; at 8 miles the sound was quite as distinct as at 1½ miles and almost as loud as at 4 miles; at 12 miles the sound was heard at times quite distinctly, and at times somewhat feebly. Even at 12 miles the sound received was sufficient to give a practicable warning signal. It has been thus demonstrated that sound may be produced in the water at a given point and picked up electrically at any point within a radius of 12 miles.

It is now proposed to install a practical working station for the use and benefit of shipping entering and leaving Boston harbor, in order that the great utility and value of the system may become known. Two bells, of different pitch, will be anchored, one on either side of Boston Light, 50 feet below the surface of the sea. These bells will be, say 5 miles apart, and each bell a mile or more from shore.

The bells will not be suspended from boats, but from submerged buoys, holding them up, and anchored to moorings holding them down, so that their position will be fixed and unchanging and properly charted. The electric power for ringing them will be supplied by insulated cables from the shore. They will be rung automatically from the power house at regular intervals, just as a flashlight is operated in a lighthouse. They will be rung simultaneously at the beginning of each minute, and at the end of 20 seconds bell No. 1 will sound one stroke, and 20 seconds later bell No. 2 will sound two strokes, each bell thus declaring its identity.

Prof. Gray invented an electrical receiver to determine the direction of the origin of the sound. It therefore becomes a simple task to draw two lines on the chart at the ascertained angles, one from each charted signal bell, and where these two lines intersect there will be the position of the ship.

Prof. Gray invented an improvement by means of which his electrical receiver operates automatically a gong in the pilot house whenever the ship comes within a given distance of one of the submerged bells. Thus a submerged bell placed near a dangerous reef would set up an automatic alarm on board any ship thus equipped the moment she came within the radius of danger. This device would have saved countless lives and thousands of vessels which have been lost by getting out of their course and going to destruction when their commanders were off their guard, because they thought themselves perfectly safe.

It is, of course, obvious that the vessels equipped with both sound-producing and sound-receiving apparatus may avoid collision, and send and receive intelligible messages to and from each other when they meet at sea. Also that lightships may be put in communication with shore stations, and that vessels passing along the coast may likewise send and receive messages to and from the shore.

Gray and Mundy patented a bell which is rung electrically, but without being struck percussively. Nothing touches it as it hangs motionless in either the air or water, but by depressing a common Morse key an electric circuit is made, which sends an alternating current to electro magnets contained in the cavity of the bell, and the magnetic lines of force thus created vibrate the bell continuously as long as the current is maintained, causing it to sound forth like a great organ pipe, but with tremendous power.

The successful ringing of a bell by this method depends upon sending precisely the proper number of impulses to the electro magnets, and this in turn depends upon maintaining an absolutely uniform rate of speed in the motor driving the generator.

The slightest change of speed will silence the bell. Prof. Gray could find no governor sufficiently sensitive to hold the

speed uniformly to the rate called for by the fundamental tone of the bell; he therefore invented a device for this purpose. It is efficient and simple.

SUCCESSFUL TEST OF OIL-FUEL APPARATUS.

Recently the steamship Khodoung, a petroleum tank steamer which has been built by Sir W. G. Armstrong, Whitworth & Co., Limited, for the Burmah Oil Co. of Rangoon, went out to sea from the Tyne for a trial of her machinery and the oil-fuel apparatus and burners. This vessel is intended for the transport in bulk of Burmah petroleum or kerosene from Rangoon to Calcutta, and all arrangements have been designed to meet these requirements. The Burmah Oil Co. has extensive oil fields and wells in Burmah. Its refinery alone, near Rangoon, employs a great number of men in the production of what is known as Oriental kerosene, bazaar oil, jute oil, and other products derived from the distillation of Burmah petroleum oil. The steamers and boilers belonging to the company use entirely for the generation of steam what is described in the East as "earth oil fuel refuse." It is, at low temperatures, of the consistency of lard, and steam coils are required to keep it in the liquid form when employed in regions of low temperature. It has a very high flash point, which, it is stated, is considerably above 200 degrees Fahrenheit. The machinery, which has been constructed by the Wallsend Slipway and Engineering Co., is of the triple-expansion type and of the newest design, having three cylinders, 19 inches, 31 inches and 51 inches in diameter, with a stroke of 36 inches, and is placed, as is usual with oil-tank steamers, at the after end of the vessel. Steam is supplied by two single-ended boilers, working at a pressure of 180 pounds per square inch. An extra large boiler is also fitted for auxiliary purposes. All the boilers, both main and auxiliary, have been designed to burn Burmah oil-fuel refuse with Orde's burners. The oil-fuel bunkers form part of the vessel and have been very strongly built, and the arrangements generally are of a complete and satisfactory nature. The oil-fuel burners, which are in duplicate to each furnace, and the arrangements in connection with the installation,

have been designed by Mr. Orde, who is connected with Sir W. G. Armstrong, Whitworth & Co. During the trial, all the oil apparatus worked in a very satisfactory manner.

The point of interest of the trial was that this was the first occasion in England of Burmah oil-fuel refuse being used for the generation of steam. A number of vessels have now been fitted on the Tyne for burning oil fuel, and there is every reason to believe that in the near future oil fuel will be more largely used; it appears only a question of time and arrangement. We have only to add that the machinery during the trial worked admirably.—"The Engineer," London.

FAST RAILROAD SPEED.

A speed of 90 miles per hour was recently made by the Black Diamond Express of the Lehigh Valley Railroad. The train consisted of four Pullman cars and an "Atlantic" type engine. This train was 13 minutes late at Rochester Junction, and on the run to Manchester an attempt to make up the lost time was made and was more than accomplished. On one section of the road a distance of 5.1 miles was made in exactly 3 minutes and 41 seconds. For the last 1,800 feet of that distance brakes were applied, slowing down for a train-order board. The first 4¾ miles, by actual blue-print measurement, were run in 3 minutes and 8 seconds. This speed was timed by three watches, which never left the hands of the men holding them. The total distance was covered at an average rate of 88 miles an hour, and the rate for the first 4¾ miles was exactly 90 miles per hour. On the same run the distance between Rochester Junction and Manchester, 20.1 miles, was covered in 19 minutes and 10 seconds. This time was taken from a standing start at Rochester Junction to a full stop a Manchester, the speed being reduced to a rate of 25 miles an hour through the Manchester yards.

ELECTRICAL SMOKE DEPOSITION.

An article on the practical possibilities of electrical smoke deposition, which would be of importance in the neighborhood

of large smoke-producing establishments. Reference is made to an old paper of Lodge, founded on Tyndall's well-known experiment, which consists in holding a heated body in the path of a ray of light, when a dark, dust-free space is produced in its neighborhood. Lodge also made the following experiment with a suspended body, which was electrified in an atmosphere artificially charged with smoke; on raising the potential to some thousands of volts, by means of an influence machine, to such a point that a brush discharge was possible, the "dark space" (that is, the dust-free space) was suddenly and rapidly widened, and the smoke being diffused, was deposited on the sides and bottom of the containing vessel. The best effects were produced when the conductor took the form of a point, the smoke depositing like a map along the direction of the lines of force. The explanation is that the smoke particles become electrified by induction and are attracted to one another, and also to the opposite pole, in a similar manner to iron filings in the vicinity of a magnet. A similar effect is obtained with vapor or damp smoke, which is condensed in the form of mist or fine rain. There are two difficulties in the practical application of this process; one is the natural draft in an active chimney or flue. If a system of pointed conductors is fitted to the top of the chimney, and surmounted at a short distance above by a cap or dome of electrified wire gauze or netting, it has been found to assit the draft, and also to condense some, though not all, of the smoke. Another plan suggested by Lodge is to suspend a sheet, or sheets, of wire netting, provided with numerous points, or barbs, longitudinally along a flue, or chimney, and to oppose an opposite conductor on the walls of the chamber in the shape of a series of points. Another difficulty lies in the insulation between the two poles, owing to the deposition on the conductors of soot and smoke particles. To obviate this, he suggests a protective insulating sleeve extending over, though not actually touching, that portion of the conductor nearest its point of support for a few inches from the latter. This would at least protect the actual fixture from deposit, and, as to the extremities of the conductors, the natural draft would probably assist in keeping them clear of

excessive deposition, at least for a certain period.—London "Electrical Review."

MAKING ROPE AT CHARLESTOWN NAVY YARD.

Making rope by hand is almost a lost art in this country. There are only two rope walks in the United States where it is practiced at present. One of these is at the Charlestown navy yard, which, by the way, is the only rope walk owned and operated by the United States government. The products now made by hand are used principally for serving wire rope, rigging and other ropes needing protection from the weather or from rubbing. They are all tarred. Included in the so-called serving cords are marline, houseline, hambroline, round line and two and three-yarn spunyarns. The Charlestown rope walk uses three kinds of hemp—Russian, Manila and Kentucky. At present rope is being made from all three. The variety which comes from our newest possession is the lightest in color and of fine quality. Recently a cargo of 400 tons was imported from the Philippines by the Government. Com. John E. Pillsbury, head of the equipment department, who has charge of the rope factory, and Superintendent Fred A. Jenks, one of the most expert rope makers in the country, are both enthusiastic over results obtained from this importation. The Russian product is a medium in color, between the light Manila and the dark Kentucky hemp. The former is finer than the latter in quality, but is not nearly so strong. Kentucky hemp is tough and coarse.

The raw product is delivered at the factory in great bales weighing nearly 300 pounds. The first step in the manufacturing process is taken when the bales are broken open and the "heads," or bunches, of hemp are taken out to be hackeled, or topped. Only a few of the old hands can do this work, as it requires a thorough knowledge of the amount of combing different qualities of hemp need in order to be ready for the spinners. A hackel is simply an immense iron comb with long teeth which stick up several inches from its back. The man who does this work takes a head of hemp and, standing some two or three feet from the comb, tosses the fibers upon it and draws

them through the sharp teeth. This is kept up until all the short fibers are culled out; then the bunch is reversed and the other half put through the same process. When the head of hemp leaves the hands of the hackeler it consits of only the long, strong fibers, and is ready to be spun into rope. The heads of fine, long hemp fibers are passed passed along to the spinners' loft, where the actual ropemaking commences. The manufacture of rope is a picturesque art, and the almost extinct hand spinner is the quaintest and most interesting feature of it. The hand spinner's loft is in the attic of the main building, and is a room some 400 feet in length. At one end is "the wheel," a large balance wheel used for furnishing power to turn four hooked spindles which are set in a frame nearby. A boy turns this wheel. At intervals down the length of the "ground," as the loft floor is called, are racks with pegs that guide the turning threads and keep them in place.

When the spinners have wrapped a bundle of hemp fibers about their bodies they look not unlike men with life preservers on. In his right hand the spinner holds a woolen cloth to aid him in guiding the strands as they slip between his fingers. With the inner part of his hand he gathers the threads and regulates their bulk as they unwind from the bunch around his waist; with his thumb and fore finger he shapes them. Slowly he walks backward as the threads are spun, the wheel giving them the necessary turn. Each of the threads is sixty fathoms long. The coil of fibers about the spinner's body is sufficient to make forty-eight threads, and in doing his day's work the spinner walks eight miles, four ahead and four backwards. When three threads have been spun they are put together between a new set of pegs, and a man holding in his hand a cone-shaped piece of wood having three grooves cut the length of it, and called the "top," placing a thread in each groove, walks rapidly up the ground toward the wheel. As they pass through the grooves, the wheel gives the required turn to the three threads of the cord. After the cords are finished they are put in a rack and kept there until seventy-five or eighty have been collected and a turn put in them.

Such a bundle of cords is called a "junk," and weighs from 350 to 400 pounds.

The "junk" is now sent down to the tar house and immersed in a trough filled with hot tar. On being removed from the tar it is passed through a curious mechanical device called a horse-shoe nipper, which squeezes all the surplus tar from the bundle. The nipper derives its name from the fact that it is shaped almost like a horse shoe. The "junk" now goes to the yarn house to season. This seasoning or drying process requires from five to six weeks, but oftentimes, when there is a rush order on hand, it is allowed much less. After the "junk" has seasoned it is spread on the ground and the turn taken out of it. Finally the cords are strapped up into coils. "Strapping," as it is technically termed, is winding the cords on a reel. The man who does this holds in his hand a short piece of tarred rope which he twists several times around the cord that is being wound on the reel, thus giving a purchase that enables him to wind it very tight. This piece of tarred rope also serves to smooth the surface of the cord, giving it a glossy appearance obtainable in no other way. So compact has the bundle now become that it retains its shape when removed from the reel. When the strapping is finished and the reel removed the bundle of cord is ready for shipment. It is thirty years since hand rope making was in its prime in the United States. One man can now do the work which it formerly took eight men to perform; a machine does about the same amount of work as a hand spinner, and one man can tend eight machines.—"Marine Review."

JAPAN AS A MARITIME NATION.

Japan now stands tenth in the list of maritime nations, having the precedence of both Holland and Denmark. She occupies this position by virtue of her aggregate steam and sailing fleets, when compared with the combined fleets of other nations. But if only the steam fleet is taken into consideration, Japan holds the fifth rank. At the end of last year the Japanese flag covered 471 ocean steamers, measuring altogether 484,000 registered

tons, so that, in this respect only England, Germany, the United States and France, stand before her. Of these 471 steamships, 126, measuring about 260,000 tons, were owned by three companies, which are carrying on a hot competition with the other maritime nations of both Europe and America. These three are the Nippon Yusen Kaisha, the Osaka Shosen Kaisha and the Toyo Kisen Kaisha. The first-named of these, which has its headquarters at Tokio, possesses a nominal capital of £2,300,000 and works with sixty-eight steamers, of nearly 200,000 tons register. It paid, for the past year, a dividend of 9½ per cent. The steamers of the company perform the following services: The European line from Yokohama to Marseilles, London and Antwerp; Bombay line from Yokohama to Colombo and Bombay; Australian line from Yokohama to Manila and Sydney; American line from Hong Kong, Kobe and Yokohama to Seattle; from Yokohama to Shanghai; from Kobe to Vladivostock; from Kobe to Newchwang; from Kobe to Tientsin; from Kobe to Chi-nan-po; and between Shanghai, Chifoo and Tientsin. Besides these services, this company runs steamers between several places on the Japanese coasts, and to Formosa. The Osaka Shosen Kaisha, which has its headquarters at Osaka, has a capital of £575,000 (which is about to be doubled), and owns fifty-five vessels aggregating about 42,000 register tons. Thirteen of these are steamers of over 1,000 tons register.

The last dividend paid by this company was 8½ per cent. Its vessels work for the most part in the Japan coasting trade, but some of them run between Japan, North China and Corea, and others between Formasa and South China. After the capital has been increased, oversea lines of steamers to Europe, India and Australia will be organized. The Toyo Kisen Kaisha has its headquarters at Tokio; works with a capital of £625,000, and possesses three steamers, each of 6,000 tons register, which keep up a regular communication between Hong Kong, Shanghai, Kobe, Yokohama and San Francisco. It is worthy of note that the subsidies granted by the Japanese government for the year 1900–1 in aid of these and some smaller shipping companies amount to £800,000.—"Syren and Shipping."

TABLE OF EFFICIENCIES ON TESTS OF BABCOCK & WILCOX MARINE BOILER FOR U. S. S. *CINCINNATI*.*

Based on evaporation per pound of dry coal.

Coal samples tested in Mahler calorimeter by E. H. Peabody and P. C. Idell.

Date of test.	Kind of coal, Pocahontas, flat top.	B. T. U. per pound dry coal.	Theoretical maximum evaporation per pound dry coal.	Water evaporated per pound dry coal from and at 212 degrees.	Efficiency.	Water evaporated per square foot heating surface, 212 degrees in boiler test.	Dry coal burned per square foot grate surface per hour.
1900.							
June 15..	Mine run	14,616	15.14	11.06	73.1	5.16	19.5
" 16.	Lump, passed over screen having 1 inch square mesh	14,956	15.49	11.51	74.3	5.57	20.2
" 18.	Do.	14,344	14.85	10.49	70.6	8.42	33.5
" 19.	Do.	14,363	14.87	10.43	70.1	8.77	35.0
" 20.	Do.	14,560	15.08	10.18	67.5	10.11	50.4
" 21.	Do.	14,253	14.76	10.19	69.0	9.59	47.8
" 22.	Nut, through 1 inch, and over $\frac{3}{4}$ inch square mesh	14,685	15.21	9.64	63.4	13.68	59.2
" 23.	Do.	14,800	15.32	11.22	73.2	6.47	22.6

* For results of tests of this boiler, see Vol. XII, No. 4.

SHIPS.

UNITED STATES.

New Battleships and Armored Cruisers.—Bids for five battleships and six armored cruisers authorized by the Acts of Congress of March 3, 1899, and June 7, 1900, were opened at the Navy Department on December 7, 1900.

These vessels were fully described in the JOURNAL, Vol. XII, Nos. 1 and 2.

Bids were received as follows:

BIDS FOR THE CONSTRUCTION OF FIVE (5) BATTLESHIPS AUTHORIZED BY THE ACTS OF MARCH 3, 1899, AND JUNE 7, 1900.

Fore River Engine Company.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered battleship of about 15,000 tons trial displacement..... $3,580,000

Delivery within 36 months.

For *two* of said battleships, each..... 3,555,000

Delivery of each within 36 months.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement..... 3,430,000

Delivery within 36 months.

For *two* of said battleships, each..... 3,405,000

Delivery of each within 36 months.

Vessels authorized by Act of June 7, 1900.

For *one* battleship, without sheathing and coppering, of about 14,600 tons trial displacement..... 3,430,000

Delivery within 36 months.

For *two* of said battleships, each..... 3,405,000

Delivery of each within 36 months.

Class II.—Bidder's plans and specifications..... No bid.

John H. Dialogue and Son.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered battleship of about 15,000 tons trial displacement..... $3,400,000

Delivery within 36 months.

For *two* of said battleships..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement..... 3,290,000

Delivery within 36 months.

For *two* of said battleships..... No bid.

Vessels authorized by Act of June 7, 1900.

For *one* battleship, without sheathing and coppering, of about 14,600 tons trial displacement..... 3,290,000

Delivery within 36 months.

For *two* of said battleships..... No bid.

Class II.—Bidder's plans and specifications..... No bid.

Moran Bros. Company.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered battleship of about 15,000 tons trial displacement..... 3,865,000

Delivery within 30 months.

For *two* of said battleships, each..... 3,749,000

Delivery: One within 30 and the other within 35 months.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement..... 3,697,000

Delivery within 30 months.

For *two* of said battleships, each..... 3,586,000

Delivery: One within 30 and the other within 35 months.

Vessels authorized by Act of June 7, 1900.

For *one* battleship, without sheathing and coppering, of about 14,600 tons trial displacement..... 3,697,000

Delivery within 30 months.

For *two* of said battleships, each..... 3,586,000

Delivery: One within 30 and the other within 35 months.

New York Shipbuilding Company.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed ("and coppered" stricken out) battleship of about 15,000 tons trial displacement..... 4,200,000

Delivery within 30 months.

For *two* of said sheathed battleships, each..... $4,175,000
Delivery, one within 30 and the other within 36 months.
Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement..... 4,100,000
Delivery within 30 months.
For *two* of said battleships..... 4,075,000
Delivery: One within 30 and the other within 36 months.

Vessels authorized by Act of June 7, 1900.
No bid for battleships under this Act was made.

Class II.—Bidder's plans and specifications..... No bid.

Union Iron Works.
Bid under Class II.—Department's plans and specifications, except specially noted omissions in the specifications attached to the bid.

Vessels authorized by Act of March 3, 1899.
No bid for battleships under this Act was made.

Vessels under the Act of June 7, 1900.
For *one* battleship, without sheathing and coppering, of about 14,600 tons trial displacement, and to have a speed of 19 knots an hour..... 3,460,000
Delivery within 36 months.
For *two* of said battleships..... No bid.

Class I.—Department's plans and specifications..... No bid.

NOTE.—The omissions referred to above are shown on the following pages of the hull specifications forming part of the bidder's proposal (Class II):

Page 50.—*Two* emergency stations changed to *one*.

Page 121.—Under the heading "Coaling Davits," the following is stricken out:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted."

Page 177.—Under the heading "Electric Plant." This is so changed that the Government is to supply the electric plant, the contractor installing it.

Page 185.—Under the heading "Completion and Acceptance." Changes concerning the electric plant are made.

Page 186.—So changed that all articles under the head of "Means of Interior Communication," are to be supplied by the Government and installed by the contractor.

NOTE.—No changes made in the machinery specifications.

Newport News Company.

Bid under Class II.—Department's plans and specifications, except specially noted omissions in the specifications attached to the bid.

Vessels authorized by Act of March 3, 1899.

For *one* battleship, sheathed and coppered, of about 14,600 tons trial displacement, and to have a speed of 19 knots an hour, $3,593,000

Delivery within 36 months.

For *two* of said battleships..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement, speed 19 knots an hour..... 3,540,000

For *two* of said battleships..... No bid.

Vessels authorized by Act of June 7, 1900.

No bid for battleships under this Act was made.

Class I.—Department's plans and specifications..... No bid.

NOTE.—The omissions referred to above are shown on the following pages of the hull specifications forming part of the bidder's proposal (Class II):

Pages 53, 54, 67 and 68.—*Two* emergency stations changed to *one*.

Page 127.—Under the heading "Coaling Davits," the following is stricken out:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted, * * * and appliances."

Page 179.—Under heading "Articles of Equipment Specified to be Supplied by the Government." This is so changed that the Government is to supply the electric plant, the contractor installing it.

Page 184.—Under heading "Electric Plant." This is so changed that the Government is to supply the electric plant, the contractor installing it.

Pages 192 and 193.—Under heading "Completion and Acceptance." Changes concerning the electric plant are made.

Page 193.—Under heading "Means of Interior Communication." So changed that all articles under this head are to be supplied by the Government, and installed by the contractor.

NOTE.—No machinery specifications accompany the bids of this company.

Cramp and Sons.

Bids under Class II.—Department's plans and specifications, except specially noted changes in the specifications attached to the bid.

Vessels authorized by Act of March 3, 1899.

For *one* battleship, sheathed (but not coppered), of about 15,000 tons trial displacement, speed 19 knots an hour..... $3,600,000

Delivery within 36 months.

For *two* of said battleships..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 14,600 tons trial displacement..... No bid.

For *two* of said battleships..... No bid.

Vessels authorized by Act of June 7, 1900.

For vessels under this act..... No bid.

Class I.—Department's plans and specifications..... No bid.

NOTE.—The changes referred to above are shown on the following pages of the hull specifications forming part of the bidder's proposal (Class II):

Page 67.—*Two* emergency stations changed to *one*.

Page 127.—Under heading "Coaling Davits," the following is ing is stricken out:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted. * * * and appliances."

Page 179.—Under "Articles of Equipment Specified to be Supplied by the Government." So changed that electric plant and supplies, and all articles included under the heading "Means of Interior Communication" are to be supplied by the Government.

Page 184.—Under heading "Electric Plant." So changed that electric plant is to be supplied by the Government, and installed by the contractor.

Page 191.—So changed that expense of transportation of generating sets, etc., are to be borne by the Government instead of by the contractor.

Pages 192 and 193.—Under heading "Completion and Acceptance." Changes concerning the electric plant are made.

Page 193.—Under heading "Means of Interior Communication." So changed that all articles specified under this heading will be supplied by the Government and installed by the contractor.

NOTE.—No machinery specifications accompany the bid of this company.

Bath Iron Works.

Bid under Class II.—Department's plans and specifications, except specially noted omissions in specifications for sheathed battleship attached to bid.

Vessels authorized by Act of March 3, 1899.

For *one* battleship, sheathed and coppered, of about 15,000 tons trial displacement, speed 19 knots an hour..... $3,590,000

Delivery within 36 months.

No other bids for vessels under this act.

Class I.—Department's plans and specifications..... No bid.

NOTE.—The omissions referred to above are shown on the following pages of the hull specifications forming part of the bidder's proposal (Class II):

Page 53.—*Two* emergency stations changed to *one*.

Page 127.—Under heading "Coaling Davits," the following is stricken out.

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted * * * and appliances."

Page 134.—Under heading "Coaling Chutes." *Hand gear* proposed for operating armored shutters.

Page 179.—Under heading "Articles of Equipment Specified to be Supplied by the Government." So changed that electric plant and supplies (E) and all articles included under the heading "Means of Interior Communication" are to be supplied by the Government.

Page 184.—Under heading "Electric Plant." So changed that the electric plant is to be supplied by the Government and installed by the contractor.

Page 191.—So changed that expenses of transportation of generating sets, etc., are to borne by the Government instead of by the contractor.

Pages 192 and 193.—Under heading "Completion and Acceptance." Changes concerning the electric plant are made.

Page 193.—Under heading "Means of Interior Communication." So changed that all articles under this heading are to be suppplied by the Government and installed by the contractor.

NOTE.—Bidder's machinery specifications the same as the Department's.

BIDS FOR THE CONSTRUCTION OF SIX (6) ARMORED CRUISERS AUTHORIZED BY THE ACTS OF MARCH 3, 1899, AND JUNE 7, 1900.

Cramp and Sons.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed (not coppered) armored cruiser of about 13,800 tons trial displacement..... $3,890,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 13,400 tons trial displacement..... No bid.

For *two* of said armored cruisers..... No bid.

Vessels authorized by Act of June 7, 1900.

For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,780,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—The specifications prepared by the Department, accompanying and forming part of the above bids, contain the following changes:

In the hull specifications for unsheathed cruisers.

Page 64.—*Two* emergency stations changed to *one*.

Page 120.—Under the heading "Coaling Davits," the following is omitted:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted."

In hull specifications for sheathed cruisers.

Page 67.—*Two* emergency stations changed to *one*.

Page 125.—Under heading "Coaling Davits," the following is omitted:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted."

No machinery specifications accompany bids.

Union Iron Works.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... $3,800,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 13,400 tons trial displacement..... 3,750,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Vessels authorized by Act of June 7, 1900.

For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,750,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—The specifications prepared by the Department, accompanying and forming part of the above bids, contain the following changes:

In hull specifications for unsheathed cruisers.

Page 64.—*Two* emergency stations changed to *one*.

Page 120.—Under heading "Coaling Davits," the following is omitted:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted * * * and appliances."

In hull specifications for sheathed cruisers.

Page 67.—*Two* emergency stations changed to *one*.

Page 125.—Under heading "Coaling Davits," the following is omitted:

"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted * * * and appliances."

NOTE.—No change made in the machinery specifications.

Newport News Company.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... 3,885,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.
Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* armored cruiser of about 13,400 tons trial displacement..... $3,775,000
Delivery within 36 months.
For *two* of said vessels..... No bid.

Vessels authorized by Act of June 7, 1900.
For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,775,000
Delivery within 36 months.
For *two* of said armored cruisers..... No bid.

N. B.—The following note appears in the margin of the proposal.
"This bid is for two ships; speed 22 knots."

Class II.—Bidder's plans and specifications..... No bid.
NOTE.—The specifications prepared by the Department, accompanying and forming part of the above bids, contain the following changes:
In the hull specifications for unsheathed cruisers.
Pages 50, 51, 64 and 65.—*Two* emergency stations changed to *one*.
Page 120.—Under heading "Coaling Davits," the following is omitted:
"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted. * * * and appliances."

In the hull specifications for sheathed cruisers.
Pages 53, 67 and 68.—*Two* emergency stations changed to *one*.
Page 125.—Under heading "Coaling Davits," the following is omitted:
"All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted. * * * and appliances."

NOTE.—No machinery specifications accompany the bids.

Fore River Engine Company.
Bids under Class I.—Department's plans and specifications.
Vessels authorized by Act of March 3, 1899.
For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... 3,975,000
Delivery within 36 months,
For *two* of said armored cruisers, each..... 3,950,000

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 13,400 tons trial displacement..... $3,800,000
Delivery within 36 months.
For *two* of said armored cruisers, each..... 3,775,000
Delivery of each within 36 months.

Vessels authorized by Act of June 7, 1900.
For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,800,000
Delivery within 36 months.
For *two* of said armored cruisers, each..... 3,775,000
Delivery of each within 36 months.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—Proposes to construct the vessels in accordance with Department's plans and specifications. No specifications accompany bids.

Moran Bros. Company.
Bids under Class I.—Department's plans and specifications.
Vessels authorized under Act of March 3, 1899.
For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... 4,132,000
Delivery within 30 months.
For *two* of said armored cruisers, each..... 4,008,000
Delivery: One within 30 and the other within 35 months.
Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 13,400 tons trial displacement..... 3,963,000
Delivery within 30 months.
For *two* of said armored cruisers, each..... 3,844,000
Delivery: One within 30 and the other within 35 months.

Vessels authorized by Act of June 7, 1900.
For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,963,000
Delivery within 30 months.
For *two* of said armored cruisers, each..... 3,844,000
Delivery within 30 months and 35 months, respectively.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—Department's hull and machinery specifications accompany the bid. No change in.

John H. Dialogue and Son.

Bids under Class I.—Department's plans and specifications.

Vessels authorized by Act of March 3, 1899.

For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... No bid.

For *two* of said armored cruisers..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering) for *one* of about 13,400 tons trial displacement..... $3,825,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Vessels authorized by Act of June 7, 1900.

For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 3,825,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—Propose to construct the vessels in accordance with Department's plans and specifications. No specifications accompanying bids.

Risdon Iron and Locomotive Works.

Bids under Class I.—Department's plans and specifications.

Vessels authorized under Act of March 3, 1899.

For *one* sheathed and coppered armored cruiser of about 13,800 tons trial displacement..... No bid.

For *two* of said armored cruisers..... No bid.

Or (in case the Secretary of the Navy should be authorized to build said vessels without sheathing and coppering), for *one* of about 13,400 tons trial displacement..... No bid.

For *two* of said armored cruisers..... No bid.

Vessels authorized by Act of June 7, 1900.

For *one* armored cruiser (not sheathed and coppered) of about 13,400 tons trial displacement..... 4,075,000

Delivery within 36 months.

For *two* of said armored cruisers..... No bid.

Class II.—Bidder's plans and specifications..... No bid.

NOTE.—Propose to construct the vessel in accordance with Department's plans and specifications. No specifications accompanying bid.

SUMMARY OF BIDS.

Three Sheathed Battleships, Act March 3, 1899, Appropriation, $3,600,000 each.

Bidder.	Ships.	Amt. bid.	Coppering.	C. & R.	Steam Eng.	Equipm't.	Total cost.	Remarks.
Dialogue	1	$3,400,000	$20,000	$58,900	$10,000	.....	$3,488,900	$111,100 under.
Fore River	1	3,580,000	20,000	58,900	10,000	.....	3,668,900	68,900 over.
Fore River	2	3,555,000	20,000	58,900	10,000	.....	3,643,900	43,900 over.
Moran	1	3,865,000	20,000	58,900	10,000	.....	3,953,900	353,900 over.
Moran	2	3,749,000	20,000	58,900	10,000	.....	3,837,900	237,900 over.
Bath	1	3,590,000	20,000	58,900	10,000	$167,500	3,846,400	246,400 over.
Newport News	1	3,593,000	20,000	58,900	10,000	167,500	3,849,400	249,400 over.
Cramp	1	3,600,000	20,000	58,900	10,000	167,500	3,856,400	256,400 over.
N. Y. S. Co.	1	4,200,000	20,000	58,900	10,000	.....	4,288,900	688,900 over.
N. Y. S. Co.	2	4,175,000	20,000	58,900	10,000	.....	4,263,900	663,900 over.

Two Battleships, Unsheathed, Act June 7, 1900, Appropriation, $3,600,000 each.

Bidder.	Ships.	Amt. bid.	C. & R.	Steam Eng.	Equipm't.	Total cost.	Remarks.
Dialogue	1	$3,290,000	$58,900	$10,000	.....	$3,358,900	$241,100 under.
Fore River	1	3,430,000	58,900	10,000	.....	3,498,900	101,100 under.
Fore River	2	3,405,000	58,900	10,000	.....	3,473,900	126,100 under.
Moran	1	3,697,000	58,900	10,000	.....	3,765,900	165,900 over.
Moran	2	3,586,000	58,900	10,000	.....	3,654,900	54,900 over.
Union Iron Works	1	3,460,000	58,900	10,000	$178,500	3,707,400	107,400 over.

Three Armored Cruisers, Sheathed, Act March 3, 1899, Appropriation, $4,000,000 each.

Bidder.	Ships.	Amt. bid.	Coppering.	C. & R.	Steam Eng.	Equipm't.	Total cost.	Remarks.
Union Iron Works	1	$3,800,000	$25,000	$55,600	$10,000	.....	$3,890,600	$109,400 under.
Newport News	1	3,885,000	25,000	55,600	10,000	.....	3,975,600	24,400 under.
Cramp	1	3,890,000	25,000	55,600	10,000	.....	3,980,600	19,400 under.
Fore River	1	3,975,000	25,000	55,600	10,000	.....	4,068,600	65,600 over.
Fore River	2	3,950,000	25,000	55,600	10,000	.....	4,040,600	40,600 over.
Moran	1	4,132,000	25,000	55,600	10,000	.. ..	4,222,600	222,600 over.
Moran	2	4,008,000	25,000	55,600	10,000	.....	4,098,600	98,600 over.

Three Armored Cruisers, Unsheathed, Act June 7, 1900, Appropriation, $4,250,000 each.

Bidder.	Ships.	Amt. bid.	C. & R.	Steam Eng.	Equipm't.	Total cost.	Remarks.
Union Iron Works	1	$3,750,000	$55,600	$10,000	.....	$3,815,600	$434,400 under.
Newport News	1	3,775,000	55,600	10,000	.....	3,840,600	409,400 under.
Cramp	1	3,780,000	55,600	10,000	.....	3,845,600	404,400 under.
Fore River	1	3,800,000	55,600	10,000	.....	3,865,600	384,400 under.
Fore River	2	3,775,000	55,600	10,000	.....	3,840,600	409,400 under.
Moran	1	3,963,000	55,600	10,000	.....	4,028,600	221,400 under.
Moran	2	3,844,000	55,600	10,000	.....	3,909,600	340,400 under.
Dialogue	1	3,825,000	55,600	10,000	.....	3,890,600	359,400 under.
Risdon Iron Works	1	4,075,000	55,600	10,000	.....	4,140,600	109,400 under.

It will be noticed that with the reservations made by the Bureaus of Construction and Repair and Steam Engineering, all bids, with the exception of that of Dialogue Bros. for the three sheathed battleships, were in excess of the appropriation. The Bath Iron Works, Newport News Company and Cramp & Sons left various items out of their specifications, estimated to be worth $167,500.

After consideration of the bids, it was decided to tender the awards to the Newport News Dry Dock Company and the Bath Iron Works on the Atlantic Coast, for the sum of $3,590,000, and to Moran Bros. & Co. at $3,590,000, plus the differential of 4 per centum in favor of the Pacific Coast, allowed by the Act; or at $3,733,000; the vessels to be built and equipped in all respects as called for by the Department's specifications, with the following exceptions, which were eliminated, viz: Power operation of watertight doors; power operation of hatches; refrigeration of magazines; laundry machinery; mattresses and pillows; metallic chiffoniers; drilling-gun mounts, and furnishing the securing bolts therefor; cellulose for cofferdams; "All appliances desirable to facilitate the most rapid possible coaling of the vessel under all conditions are to be supplied and fitted."

At the present date, February 15, 1901, the contracts stand awarded, as follows:

Three sheathed battleships.

One to Newport News Dry Dock Company, at .	$3,590,000
One to Bath Iron Works, at	3,590,000
One to Moran Bros., at	3,733,000

Contracts not yet signed.

Two unsheathed battleships.

To Fore River Engine Company, contracts not yet signed, each . $3,405,000

Three armored cruisers, sheathed.

	Price.	Date of signing contract.
Armored cruiser No. 4.		
To Wm. Cramp & Sons, . .	3,890,000	Jan. 10, '01
Armored cruiser No. 5.		
To Newport News S. B. and D. D. Co.,	3,885,000	Jan. 24, '01
Armored cruiser No. 6.		
To Union Iron Works, . .	3,800,000	Jan. 10, '01

Three armored cruisers, unsheathed.

	Price.	Date of signing contract.
Armored cruiser No. 7.		
To Wm. Cramp & Sons, . .	3,780,000	Jan. 10, '01
Armored cruiser No. 8.		
To Newport News S. B. and D. D. Co.,	3,775,000	Jan. 24, '01
Armored cruiser No. 9.		
To Union Iron Works, . .	3,750,000	Jan. 10, '01

Bid for the Construction of Three Protected Cruisers authorized by Act of June 7, 1900, and described in Vol. XII, No. 4, of the JOURNAL, were opened at the Navy Department on February 1, 1901.

Four bids were received as follows:

NOTE.—All proposals, both Class I and Class II, are for vessels of a trial displacement of 9,700 tons, of 22 knots speed, and to be delivered within 36 months from date of contract.

The Neafie & Levy Ship and Engine Building Co. (Class I proposal.)

For *one* cruiser at $2,740,000.

To be built in accordance with the Department's plans and specifications, with the exception of the following items, which are to be eliminated from the specifications:

Interior communication system.
Watertight doors operated by power.
Hatch covers operated by power.
Awnings and canvas work.
Bronze pilot house. (One of wood to be substituted.)
Cellulose. (To be supplied by the Government.)
Linoleum. (To be supplied by the Government.)

Newport News Shipbuilding and Dry Dock Co. (Class II proposal.)

For *one* cruiser at $2,741,000.

To be built in accordance with the Department's plans and specifications, with the exception of the changes noted in red ink on certain pages of the specifications. The changes made in hull specifications were too numerous to give in detail, and practically consisted of rewriting the specifications.

Machinery specifications: Refrigerating pipes to and coils in magazines to be omitted.

Bath Iron Works. (Class II proposal.)

For *one* cruiser at $2,750,000.

To be built in accordance with the Department's plans and specifications, with the exception of the changes noted in red ink on the following pages of the specifications. The changes made in the *hull* specifications were too numerous to give in detail, and practically consisted of rewriting the specifications.

Machinery specifications: Refrigerating pipes to and coils in magazines to be omitted.

William R. Trigg Company.

No formal proposal submitted, but in a letter to the Secretary the company stated that they would agree to build one of the cruisers for $2,780,000, or two for $5,480,000, being $2,740,000 each, provided no reduction be made for the purchase of armor, and provided further that various items enumerated be stricken from the specifications.

It was decided to tender an offer of one ship to The Neafie & Levy Ship and Engine Building Company, at $2,740,000, provided they adhered to the Government specifications and restored the following items eliminated from the specifications in their bids, viz:

1. Interior-communication system.
2. Awnings and canvas work.
3. Bronze pilot house.
4. Linoleum.

That in place of these items, the following items, the same as had been eliminated from the specifications of the battleships and armored cruisers, should be eliminated, viz:

1. Refrigeration of magazines.
2. Laundry machinery.
3. Chiffoniers.
4. Matresses and pillows.
5. Drilling-gun mounts and furnishing the securing bolts therefor.

This tender was accepted by the Neafie & Levy Company.

Tenders were also made to the Newport News Company and Bath Iron Works, being the next lowest bidders, at the same price ($2,740,000) and under the same conditions, but up to date (February 15, 1901) these firms have not been heard from.

Barney.—On December 1, 1900, torpedo boat No. 25, the *Barney*, described in Vol. X, p. 818, of the JOURNAL, was run over the Southport course on a series of screw-standardizing trials by the contractors, the Bath Iron Works. Complete sets of indicator cards and data were taken for each run.

The trials were successful in all respects, and the boat is all ready to run off her contract trial as soon as the ice is out of the harbor.

The data of these trials are given below:

Length of course, feet	6,080.
Condition of sea	smooth.
wind	calm.
weather	clear.
Draft, forward, inches	start, 60; return, 58
aft, inches	start, 60; return, 59
mean, inches	start, 60; return, 58.5
Displacement, tons	start, 172; return, 164
Mean displacement tons	168
Time of low water	11·50 A. M.

Blakely.—The torpedo boat *Blakely* (described on p. 818, Vol. X, of JOURNAL) was launched on November 22, at the works of George Lawley & Son, South Boston, Mass. The *Blakely* is named for Captain Johnston Blakely, who became famous as commander of the fighting ship *Wasp*, in the war of 1812. She was christened by Miss Nellie M. White, of Winchendon Springs. The dimensions are: Length on load water line, 175 feet; extreme breadth, 17 feet 6 inches; mean draught, 4 feet 8 inches; displacement, 165 tons; gross tonnage, 224.18 tons.

De Long.—Mrs. Sophie De Long Miles went through the formality of naming the *De Long* on November 22, at Lawley's shipyard, South Boston, Mass., although the boat was not launched, the water at high tide being too low. She was

Measured Mile Speed Trials of Torpedo Boat *Barney*, for Standardization of Screws.

Number of run	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Direction of run	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Time of day	12'17	12'29	12'43	12'53	1'05	1'17	1'27	1'39	1'53	2'02	2'15	2'26	2'37	2'44
Time of run, min., sec	5'1⅞	3'59⅛	3'56½	3'11	3'13	2'54	2'51¼	2'38⅞	2'33¼	2'15½	2'14¾	2'15½	2 10½	2'11½
Revolutions by counter, S.	620	652	641.5	692	670	672	660	658	650	657	643 5	682	663.5	663
P.	629	644	634	647.5	648	681	676 5	690.7	676.5	680	676	653.5	659	671
Revolutions per minute, S.	123.5	163 4	162.8	217.6	208 1	231 7	231.6	249.3	254.9	290.7	286	301.8	305.1	302.5
P.	125.3	161.4	160.9	203.6	201.3	234.8	237 4	261.7	265 3	300 9	300	289.2	303	306.1
mean	124.4	162.4	161.8	210.6	204.7	233.3	234.5	255.5	260.1	295.8	293.2	295.5	304	304.3
Speed, knots, mean	11.95	15.04	15.23	18.87	18.64	20.69	21.05	22.73	23.53	26.55	26.67	26.55	27.59	27.37
Steam pressure, boilers	200	193.5	190	182.5	196	195	207.5	204	208	230	230	230	230	230
1st receiver, S.	35	70	70	150	135	155	170	190	195	225	223	220	220	210
P.	42	62	60	92	100	149	150	191	180	200	212	227	228	...
2d receiver, S.	5	18	17	55	45	60	65	75	80	85	80	80	80	80
P.	11	18	18	34	34	57	62	81	78	94	94	97	95	...
3d receiver, S.	−5½	−1.25	−1.5	11	7	12	13	17	19	29	26	30	29	28
P.	−3	−0.5	+0.5	−0.25	−0.25	12.5	14	21 5	21.5	28	29½	29	27.75	...
Vaccuum in condenser, S.	25.5	26	25.75	25 25	25.5	25.5	25.5	25.25	25	23.75	24	22	22	23.5
P.	22.5	24.25	24.75	24.25	24.75	24.25	24.5	24.25	24	23.5	22.87	23.5	23.5	...
Air press. fire room, ins., S.	0	.75	...	...	...	...	...	...	...	6.25	6	6	6	...
P.	.25	0	1.5	1.5	1.25	1	1.375	2	4.25	4.87	5	4.75	4 37	...
Temperature, injection	47½	47½	47½	47½	47½	47½	47½	47½	47½	47½	47¼	47½	47½	...
delivery, S.	62	63	62	68	68	68	68	68	69	72	70	76	74	74
P.	50	50	50	52	55	56	56	60	59	62	66	59	63	...
hot well, S.	74	79	68	92	90	92	92	94	96	100	100	108	108	108
P.	74	76	80	83	86	96	92	98	98	104	106	104	102	...
feed water, S.	186	204	196	230	224	230	230	234	236	236	238	228	226	226
P.	190	206	212	220	218	230	232	240	240	242	242	242	242	...
Opening of throttle	.09	.09	.09	.01	.07	.1	.1	Wide	Wide	Wide	Wide	Wide	Wide	Wide
Indicated horsepower, S.	148	333	325	866	723	961	1001	1165	1243	1948	1782	2143	2082	...
P.	150	286	291	530	564	971	1017	1394	1451	1922	1999	1863	1848	No card.
Total	298	619	616	1396	1287	1932	2018	2559	2694	3870	3781	4006	3930	...

launched privately on November 23. The *De Long* is one of the eight torpedo boats ordered by the Government in the fall of 1898 (described on page 818, Vol. X, of the JOURNAL). She is named for George Washington De Long, Lieutenant Commander of the U. S. Navy, the Arctic explorer. The vessel's dimensions are as follows: Length on load water line, 175 feet; extreme breath, 17 feet 6 inches; mean draught, 4 feet 8 inches; displacement, 165 tons; gross tonnage, 226.18 tons.

Holland.—A trial of the submarine torpedo boat *Holland* was made on January 8–10, 1901, to collect data in regard to the steaming radius of that vessel when running on the surface. The following are the official reports of Lieutenant Commander Edwards and the commanding officer of the boat, Lieut. H. H. Caldwell, in regard to the trial:

January 14, 1901.

SIR: 1. In obedience to the Department's order of January 5, and the Bureau's instructions of January 7, to collect data of the speed-endurance trial of the submarine boat *Holland*, I respectfully submit the following report:

BRIEF DESCRIPTION OF THE HOLLAND.

2. The hull of this submarine boat is practically a spindle, every vertical transverse section of which is a circle. The greatest diameter is about 11 feet, the ends being about 3 feet. With such a contour the mechanical appliances must necessarily be crowded together.

3. Under surface propulsion the motive power is a gas engine of about 45 horsepower. From the shaft of this engine a set of gearing operates the propeller shaft. For want of air, as well as by reason of the danger of using gasoline, this engine cannot be worked under water.

4. For submarine propulsion electric motors are used. These motors are worked by a current of electricity from a storage battery. The main motor, through a set of gearing, works the propeller shaft, while the auxiliary motor operates the bilge pump and also an air compressor.

5. There is a steering engine for working the vertical rudder

and a diving engine for working the two horizontal rudders. These two engines are worked by air from six storage flasks. These two engines have oil-controlling cylinders.

6. There is a storage battery which is charged by the gas engine working a dynamo. This dynamo is convertible into the submarine propelling motor. There is also an ignition battery for producing explosion in the gas engine. This small battery is of low voltage and is also charged by the gas engine.

7. The storage flasks are charged to 2,000 pounds pressure. The steering and diving engines are worked by an air pressure of 50 pounds, a reducing valve preventing higher pressures reaching these appliances. A pressure of only 10 pounds is required for blowing out the submersion tanks, another reducing valve controlling this pressure.

TIME OF TRIAL.

8. The *Holland* started from Annapolis 1·30 P. M. Tuesday, January 8, and reached the navy yard, Norfolk, about 1·30 P. M., Thursday, January 10. She was actually under way twenty-five hours and thirty-six minutes. She made one stop of about three-quarters of an hour on account of the propeller motor gearing running warm. She made a second stop of about five hours to recharge the storage battery. This stop was made sixteen hours after she left Annapolis. A third stop of two hours was made on account of the after-line bearing becoming warm. After she had been under way, repairing, or charging her storage batteries for thirty-six hours she anchored for about thirteen hours to give the running crew a needed rest.

DISTANCE.

9. The actual distance run by the *Holland*, as furnished by her commanding officer, was 145 miles.

WEATHER.

10. The weather throughout the trip was favorable for the trial. I was informed by the boatswain commanding the U. S. tug *Standish*, which convoyed the *Holland*, that probably at no time during the winter would conditions be more favorable for

the test. The boatswain commanding the *Standish* has been taking tugs up and down the Chesapeake for the past ten years, and he ought to be particularly well qualified for giving an opinion as to the weather conditions.

11. When the wind was against the tide during the trip there was a little sea. There was no fog at any time, and only for three short periods was there any rain. In general, more favorable conditions could not have been expected at this season of the year.

SPEED.

12. The trip was entirely a surface run. While actually under way the speed secured was exactly $5\frac{2}{3}$ knots. The maximum speed over the ground was 7 knots. There was no log-recording machine on either the *Standish* or the *Holland*, so the speed could only be ascertained by noting the time between shore stations. The tide question can be thrown out of consideration, since the *Holland* had as much tide in her favor as against her.

DISPLACEMENT.

13. The *Holland* had about 18 inches free board. Her three torpedoes had been left on shore. The oil tanks were practically full. For about one-third of the time two extra passengers were carried, in addition to the regular Navy crew. For two-thirds of the time only one passenger was carried beyond the regular crew.

PERSONNEL.

14. There was a thoroughly competent and trained crew in the boat during the run. Two years ago I watched the civilian crew of the *Holland* manipulate her machinery, and the Navy crew was their equal in nerve, skill and readiness of resource. The *Holland* was, therefore, not at any disadvantage in respect to personnel.

15. For months preceding the time that the Navy crew were placed in charge, Lieut. H. H. Caldwell, the commanding officer of the *Holland*, had seen the civilian crew of the submarine boat work her appliances, and therefore he had an excellent chance to compare the efficiency of the two crews. Lieutenant Caldwell

not only informed me that the Navy crew were perfectly familiar with the working of the *Holland*, but also that the various mechanical appliances were in better condition than when the Navy crew were placed in charge.

16. For hours I personally watched the Navy crew carry on their work, and they were thoroughly competent to perform their duties.

CASUALTIES.

17. While starting up the electric motor, after stopping to charge the batteries, one of the bars of the armature of this motor burnt out, thus entirely throwing the electric propelling engine out of use.

18. Fortunately for the test, both the storage and ignition batteries as well as four of the six air flasks had been completely charged; otherwise the test might have ended at that point. The disablement of this motor prevented the propeller backing. It also prevented the recharging of the air flask and storage batteries. The boat would therefore be helpless when either the air supply, the ignition current, or the storage electric current should be exhausted.

CONDITION OF MACHINERY.

19. The armature of the dynamo had been turned over to the Government in an impaired condition. Previous to the acceptance of the *Holland* by the Navy Department this submarine boat had been sunk by accident somewhere on Long Island Sound. The salt water had impaired the armature, and thus trouble has been had with the motor ever since.

20. The impairment has been of such a nature that mechanics from Philadelphia have heretofore been called upon to fit new bars to the armature. The Holland people have also appreciated the serious condition of affairs, for at their own expense they are now having a new armature made, which will be ready for installation about February 1.

21. With the exception of the impaired dynamo, which the Navy crew was not at all responsible for, the condition of machinery was very good. I was informed by the commanding

officer of the *Holland* that it was now in better shape than when it was turned over to the Government.

22. Both the propeller and driving shafts need lining up. I understand the Navy crew have improved matters in this respect also, for a hot bearing was a much more frequent occurrence when they took charge than it is now.

Oil Consumption.

23. While actually under way the average oil consumption was 5 gallons per hour. The oil-tank capacity is about 1,300 gallons. The oil used during the entire trip between Annapolis and Norfolk was 175 gallons. If it was only a question of oil consumption, therefore, the boat would have a large steaming radius.

Endurance.

24. The endurance of the *Holland* is not only dependent upon her fuel supply, but also upon the physical strength of the crew. Careful watch must be kept while the batteries are being charged, as well as when the propelling engines are in operation, and there must naturally be a limit as to the time when men can remain continuously at work.

25. The facilities for sleeping, as well as for cooking, must be limited, and it is therefore a question as to whether the crew can remain aboard at sea for needed rest.

Temperatures.

26. Since the *Holland* is practically a steel spindle and has no non-conduction substances over her hull plates, the temperature during the test did not rise over 60 degrees Fahrenheit. In fact, it was so cold that one of the crew told me that he was not able to sleep while not standing watch.

27. During the first half of the run two electric heaters were used to make the men comfortable. During the last half of the run it was not deemed advisable to use them, since they consumed so much current of electricity that it was apprehensive that the storage battery would run down.

28. Since the sea was smooth during the speed-endurance trial,

the ventilators and the hatches, of course, could be used in the most efficient manner for securing desirable temperatures.

PAST PERFORMANCES OF THE "HOLLAND."

29. While on the *Holland* I was permitted to look over her log books. These records extended over a period of at least one year. I could find no evidence that either the electric propelling motor or the gas engine had ever been previously in continuous operation for a period of six successive hours. It is extremely doubtful if the boat ever previously ran, under surface propulsion, a continuous run of over 30 miles.

30. I was informed that the boat was towed from New York to Washington when she was brought around to the latter city to be inspected by the Senate and House naval committees.

31. With the exception of running a few hours under her own motive power, she was towed from Washington to Newport, R. I. The tug *Josephine* towed her to New York and the U. S. tug *Osceola* towed her from New York to Newport.

32. After being at Newport several months the *Holland* was towed, with the exception of about 12 miles from that port to Annapolis, Md., the U. S. steam tug *Leyden* and the U. S. gunboat *Alvarado* being employed to tow her between Newport and Annapolis.

33. I have even been informed that when the *Holland* was at Washington for the benefit of the Navy Department and the naval committees a tug occasionally towed her to the points where she dived and maneuvered for the instruction of the Government officials.

VENTILATION.

34. For surface propulsion, barring accidents, the boat is well arranged for securing good ventilation. Directly over the gas engine is a ventilator, and in the base of this ventilator is an electric blower. The conning tower serves as an excellent air shaft. There is a second ventilator, so that it is possible to secure a good circulation in the hull. For surface work, therefore, only an accident to the gas engine could cause discomfort or danger to the occupants.

35. Under submarine conditions, however, different ventilation can be expected. The ventilators and hatches must of necessity be closed. Gasoline is a great searcher, and if there is a defective joint or weakness in the piping it will be found by this combustible. One of the resultant products of combustion of gasoline is carbonic oxide (carbon monoxide), a deadly poison. Since this gas is odorless, it is particularly dangerous by reason of its insidiousness. Although the gas engine will not be used for submarine work, yet an accident may happen which may cause the gasoline to leak, and in this manner the odorless deadly poisons may be formed.

36. A short personal experience of my own during this speed trial may show how it affects others than the regular crew. The first hour that I spent in the engine room of the *Holland* was an exceedingly trying one, for there was just enough odor from the gas to make me uncomfortable. Afterwards I became accustomed to existing conditions, and did not seem to notice any disagreeable odor for the rest of the day. The following morning, however, I not only had something of a headache, but for several hours experienced a nervous sensation which I have never undergone before. The crew who were in the engine room about three times as long as I was, it is but fair to state, did not seem to be affected in any manner.

Defects of Mechanical Design Arrangements.

37. In using three distinct systems for securing mechanical energy the *Holland* has an inherent weakness. In this small boat of 75 tons, gasoline, electricity and compressed air are used for different purposes.

38. Gasoline is extremely liable to catch fire. At least one of its products of combustion is extremely dangerous to life. It is very attenuated, and, therefore, a great searcher. If there is a defective joint or pipe or leaky valve the gasoline will find it. When it is used in an engine that appliance should be in excellent condition. After the armature of the motor burnt out it became necessary to start the gas engine without the assistance of the electric motor. To secure the requisite amount of air for

insuring an explosion at the start recourse was had to the reduced air pressure in the pipes. It took at least twelve minutes to start the engine in this way. During the effort there was a small discharge of gas into the hull from some improper working of the valve. Even from this small leakage the machinist in charge of the motor became very much distressed, and when he came on deck to overcome this faintness by securing fresh air, he appeared very pallid and not far from collapsing. This sight impressed forcibly upon my mind the danger of using gasoline.

39. In a boat of the character of the *Holland* it must be difficult to keep the electric motors in a high state of efficiency. The compartment must of necessity be damp, and therefore drops of water are likely to fall on every part of the dynamo. Salt water is likely to fall down the hatches and ventilators, thus impairing the ventilation. Through accident the boat is likely to sink at her dock, for this very mishap has occurred when the inventor was trying to sell the boat to the Government.

40. The air flasks may be an element of danger, since they are charged with pressure of 2,000 pounds. The explosion of any one of these tanks would destroy the vessel. There are reducing valves for regulating this pressure, but any careless, inexperienced, or evil-disposed person might cause a serious casualty to the boat by tampering with the reducing valves. These valves are so exposed that it will not be a difficult matter to tamper with them.

41. The gas engine is so closely installed to both the main and auxiliary motors that it will be a very difficult matter to do any extensive overhauling or make important repairs. In fact, the three appliances are so bunched together that it will take at least ten working days to line up the shafts for this little craft.

42. There are three sets of gearing. The gas engine is geared to the main shaft. The main motor is also geared to this shaft. The auxiliary motor is geared to a countershaft, which works the bilge pump and air compressor. The use of gearing on board any ship is at least inadvisable, for no matter how strong the hull is made there must be in a seaway some working of

the vessel, and therefore the strain on the gear at times must be very great.

43. The noise in the engine room is a serious disadvantage. Since the gas engine is subjected to shock rather than to steady pressure, and since it has tripping arrangements for admitting the gas, the engine itself makes considerable noise. The electric motor must not only be kept in readiness for backing purposes, but also for quickly starting the gas engine, and so there is noise from the motor's set of gearing. Since the compressor is kept in continuous operation to maintain the pressure in the air flask, there is noise from that gearing. There is noise from the gearing between the gas engine and the propeller shafts.

44. Any accident to the ignation battery would throw the gas engine out of operation, and it would appear that this may prove a serious weakness.

45. From the above it will be observed that the *Holland* has serious mechanical weaknesses. From each of the three motive powers—compressed air, gasoline and electricity—accident or danger, due to the conditions of installation, may happen at any time.

THE "HOLLAND" APPEARS TO HAVE NO UNUSUAL APPLIANCES.

46. The *Holland* appeared to me as a spindle-shaped boat with very little freeboard. Even for the surface propulsion she need have no superstructure except the conning tower. It is extremely doubtful if she is much more visible under many conditions when she runs semi-submerged than when she runs as a submarine craft. It would be extremely difficult for any enemy to detect her, but it would also be extremely difficult for any enemy to sight any gasoline or electrical launch that had a spindle hull.

47. Every appliance that was installed was either a commercial auxiliary, or else it was of such a nature that a substitute could be secured from any large supply house.

48. I not only looked for, but made inquiry for, any distinctive invention. There was pointed out to me a tank constructed between two frames, which was said to have been one of the

special inventions granted by the Patent Office. This simple compensating tank is filled with water when one of the torpedoes is removed. A hydrostatic piston was attached to the steering engines, but this appliance has been in common use. This piston was said to have been a distinctive feature of the boat.

49. The firm plate of the maker was on most of the auxiliaries, and there appeared no evidence that any of them were special contrivances. There was reason to believe that during the past two years there have been marked improvements in the mechanical details of construction, for numerous changes were pointed out which have proved beneficial.

General Remarks.

50. Previous to the speed-endurance trial the *Holland* had been at the Naval Academy for about two months. She was probably in as serviceable a condition during the trial as she had ever been before. She had made numerous short runs at Annapolis, and quite a number of the officers of the Academy had accompanied Lieutenant Caldwell in his dives. Some new castings had been fitted, and, so far as the design and conditions would permit, various adjustments and overhaulings had been made.

51. The Navy crew of the *Holland* had a great pride in the boat, and they had done everything that the resources of the Academy would permit and their observation would suggest to make the boat more efficient as well as comfortable. Under the direction of the commanding officer of the *Holland* there had been fitted a grating deck, which was found a very great convenience. If it had not been for this improvement alone it is doubtful if the *Holland* crew could have stood as long a watch as they did after leaving Annapolis.

52. From what I saw after nine successive hours of observation, and from an examination of the machinery of the *Holland* after she reached Norfolk, I am convinced that it was through the skill, endurance and pluck of the commanding officer and the crew of the *Holland* that the boat performed as well as she did. There were several of the crew, besides Lieutenant Caldwell, who were practically on duty continuously for eighteen hours after

leaving Annapolis. During that period they had no cooked meals, but ate from a lunch basket, and there was not one of them who could assume even a comfortable position in carrying on his work. The atmosphere was very humid, and with a low temperature there must of necessity have been depressing conditions. The machinist operating the gas engine and the electrician who was in charge of the motors were almost continuously on duty for thirty hours after leaving the Naval Academy, for during the first three stoppages they had to remain at their posts to make adjustments and to charge the storage battery.

53. Personally, I am satisfied that no civilian crew could or would have done better, and therefore the Holland Company could not have secured better results if they had been permitted to send experts on board.

54. In conclusion, I desire that the Bureau would express in some official manner its appreciation of the interest Lieutenant Caldwell took in securing for the Bureau the general information called for.

Very respectfully, JOHN R. EDWARDS,
Lieutenant Commander, U. S. N.

THE CHIEF OF THE BUREAU OF STEAM ENGINEERING.

REPORT OF LIEUT. H. H. CALDWELL, COMMANDING "HOLLAND," TO SECRETARY OF THE NAVY, DESCRIBING TRIP OF "HOLLAND" FROM ANNAPOLIS, MD., TO NORFOLK, VA.

U. S. S. "HOLLAND,"
NAVY YARD, NORFOLK, VA., *January 11, 1901.*

SIR: 1. I have the honor to submit the following report of the surface run of the *Holland* from Annapolis to this port in obedience to the Department's order No. 247,611—HHW, of the 3d instant:

2. The entire run from Annapolis Harbor to alongside the wharf at this yard was under the gas engine and without any assistance.

3. Got under way and started ahead under gas engine at 1·35 P. M., January 8, followed by the U. S. tug *Standish* as convoy; Lieut. (junior grade) R. Z. Johnston as passenger. At 6·15 P. M., off Sharp Island light, stopped to cool bearing of driven

gear of motor (running as an idler) which had heated. Started ahead at 7·04 P. M.

4. Stopped at 4.35 A. M. to replace forward igniter, the packing of which had blown out. Directed *Standish* to anchor and secured astern of her to recharge storage battery, which had become much run down from the use of a new electric heater. Ran gas engine on motor, charging battery, for four hours. The use of the heater was discontinued, it not being necessary.

5. At 11·02 A. M. got under way and continued run down the bay. Lieut. Commander J. R. Edwards and Lieut. (junior grade) R. Z. Johnston as passengers. At 12·30 P. M. the after main-shaft bearing became heated; stopped to cool it. At 1·30, in attempting to start gas engine with motor, it was discovered that an armature bar of the latter was burnt out, disabling the motor. This accident has occurred several times since the boat has been under my charge and before, and is probably due to some inherent defect in the insulation. This armature has been condemned, and a new one will shortly be installed in its place.

6. Although the boat was now without means of reversing, it was decided to continue the run, and at 2·35 P. M. started the gas engine with the mixture and stood down the bay, followed by the *Standish.*

7. At 7·30 P. M., off New Point Comfort Light, directed the *Standish* to anchor for the night and secured astern of her.

8. At 8·20 A. M., January 10, got under way under gas engine and stood down the bay, through Hampton roads and up Elizabeth River, followed by the *Standish.* Lieutenant (junior grade) F. P. Baldwin as passenger. At 2 P. M. secured alongside wharf at navy yard.

9. Lieutenant Commander Edwards was carried as passenger under detail from the Department for the purpose of collecting data in regard to cruising radius. Lieutenants Baldwin and Johnston were detailed by the Superintendent of the Naval Academy for instruction.

10. The behavior of the boat and of all mechanisms was excellent in every respect, with the exceptions noted. The heating of the bearings was probably due to the shaft being some-

what out of line, and it is recommended that it be lined up when the new armature is installed. Some apprehension had been felt that the air in the boat would become bad after running the gas engine so long, but no inconvenience from that source was experienced.

11. Data:

a. Distance run, 145 knots.

b. Time underway, 25 hours 36 minutes.

c. Average speed, 5.67 knots.

d. Maximum speed, 7 knots.

e. Consumption of gasoline for propulsion, 125 gallons.

f. Consumption of gasoline for charging battery, 20 gallons.

g. Capacity of gasoline tank, 1,300 gallons.

h. Reserve capacity (ballast tanks), 3,500 gallons (approximating).

i. Consumption of engine oil, 12 gallons.

The air storage is comprised in three sets of flasks (each of about 12 cubic feet capacity) with air at a pressure of 2,100 pounds per square inch. For convenience in comparing supply with consumption this is referred to as 6,300 pounds of air. The compressor can raise the pressure in any one set of flasks about 350 pounds per hour. Using this notation:

k. Amount of air in flasks at begining of run, 6,300 pounds.

l. Air compressed during run, 8,850 pounds.

m. Air remaining at end of run, 2,600 pounds.

n. Air used during run, 12,500 pounds.

o. Average consumption of air per hour for steering engine and whistle, 488 pounds.

p. Voltage on battery at beginning of run, 126.

q. Voltage at beginning of recharging, January 9, 109.

r. Voltage at end of recharging, 124.

s. Voltage at end of run, 120.

t. Maximum temperature in boat (engine compartment, engine running), 60 degrees Fahrenheit.

u. Minimum temperature in boat, 45 degrees Fahrenheit.

v. Weather, generally fair.

w. Wind, moderate to light southerly breeze.

x. Sea, generally choppy.
y. Draught, 8 feet 6 inches.
z. Condition of bottom, foul.
a. Pitching and rolling, not noticeable.

Very respectfully,

H. H. CALDWELL,
Lieutenant, U. S. N., Commanding.

THE SECRETARY OF THE NAVY,
Navy Department, Washington, D. C.

Macdonough.—The torpedo-boat destroyer *Macdonough* (described on p. 818, Vol. X, of JOURNAL) was successfully launched at the yards of the Fore River Engine Company, Weymouth, Mass., on Monday, December 24. An effort was made to launch her on Saturday but the grease froze on the ways. The boat will shortly have a builders' trial over the Cape Ann course. The Macdonough has excited much interest among naval men because she is one of a new type. Her dimensions are: Length, 242 feet; beam, 22 feet; depth from deck to keel, 14 feet; draught, 6 feet 8 inches. No part of the vessel is armored save the forward conning towers, which are covered with $\frac{3}{4}$-inch nickel-steel. The engines are only protected by the coal bunkers, which extend for 100 feet amidships on either side, and which have a capacity for 150 tons of coal, sufficient to provide a speed of 14 miles an hour for 4,000 miles. The outer hull is of $\frac{1}{2}$-inch steel plates. This shell would be pierced if struck by a projectile. The vessel, however, is built with twelve separate watertight compartments. There are two conning towers. Accommodations are provided for a crew of eighty officers and men. The ship presents the innovation of having the officers' quarters forward and those of the crew aft. Underneath the living deck and forward of the boilers is a watertight deck.

A clever device of the *Macdonough* is an arrangement of telescopic masts mounted on the forward bridge, to which the searchlight is fixed. These masts can be shot up in a second, and as quickly lowered. The armament of the *Macdonough* will consist of four 14-pounder 3-inch rapid-fire guns and three 6-pounders. The 14-pounders will be placed one on top of the

forward tower and three on the center line of the vessel. One 6-pounder will be located on each side of the forward tower and the other will be on the after bridge. The two 18-inch torpedo tubes are located in the stern, one forward and one aft of the after conning tower. The after one will be used to discharge the torpedo when the vessel is swinging away from the object of attack and the forward one will be more for a broadside fire. Two spare torpedoes will be stored in watertight cases with watertight covers, one on each side of the deck, located so that they can be lifted by cranes to the torpedo tubes directly from the cases.

Stockton.—The torpedo boat *Stockton*, built by the Wm. R. Trigg Co., of Richmond, Va., had her official full-power trial on November 28, in Chesapeake Bay.

The following are the data of the vessel and trial:

Hull.—Length between perpendiculars, 175 feet; beam, 17 feet; displacement, designed, 160 tons; displacement on trial, 200 tons.

Main Engines.—Type, twin-screw, vertical, direct-acting, triple-expansion, 4-cylinder; diameter and stroke of cylinders, $\frac{14 \times 22\frac{1}{8} \times 25\frac{1}{4} \times 25\frac{1}{4}}{18 \text{ inches}}$; cooling surface of condensers, 2,500.8 square feet.

The air pumps are worked from eccentrics on the main shaft. They are vertical, double acting pumps having cylinders 11 inches in diameter by 6 inches stroke.

The circulating pumps, used to supplement main injection or when vessel is stopped, are centrifugal pumps, 18-inch runners, each being driven by a single cylinder 4 inches in diameter and 3 inches stroke.

There are three feed pumps of the Blake vertical, simplex pattern with steam cylinders 10 inches diameter, water-cylinders 6 inches diameter, and 12 inches stroke.

There is a fire and bilge pump in the after engine room of same pattern as feed pumps, having a steam cylinder 6 inches diameter, water cylinder 6 inches diameter, and 12 inches stroke.

There is an evaporating and distilling plant in the after fire

room consisting of two Baird-Davidson evaporators with 40 square feet tube-heating surface each, and one distiller having 12 square feet of cooling surface. The estimated output of evaporators is 1,000 gallons per 24 hours.

Feed water tank capacity, 1,920 gallons.

Boilers.—There are three boilers of the Thornycroft "Speedy" type. Length of grates, 6 feet 9 inches; grate surface, one boiler, 45.6 square feet; grate surface, all boilers, 136.8 square feet; heating surface, one boiler, 2,516 square feet; heating surface, all boilers 7,548 square feet; working pressure, 250 pounds. All boiler tubes are of solid-drawn steel, No. 11 B.W.G in thickness.

Propellers.—Type, modified Griffiths; blades bent back 9 inches; starboard propeller, left hand; port propeller, right hand; propellers turn inboard at top; material, manganese-bronze of about 66,000 pounds, T.S., tinned; diameter, 5 feet 8 inches; pitch, 8.95 feet; helicoidal area, 10.24 square feet; the weight of all machinery with water, 85.38 tons. Preliminary trials, for standardizing the screws, were made on November 16, over the measured-mile course in Chesapeake Bay, the results being given in the following table.

TABLE I.

	First double run.		Second double run.		Third double run.		Fourth double run.		Fifth double run.	
Direction of run	N	S	N	S	N	S	N	S	N	S
Duration of run, minutes and seconds	3–29.7	3–37.4	2–48	2–55.6	2–36.6	2–44	2–27.9	2–34	2–18.3	2–26.5
Speed of vessel	17.17	16.56	21.37	20.50	22.99	21.95	24.34	23.38	26.03	24.57
Total revolutions during run by counters:										
Starboard	761	793	803	838	801	834	798	829	808	838
Port	761	789	808	838	812	841	810	842	815	837
Mean revolutions per minute during run	217.7	218.3	286.8	286.3	309	306.4	326.2	325.5	352.1	343
Mean speed of vessel during double run	16.865		20.935		22.470		23.860		25.300	
Slip of screws	12.40		17.25		17.35		17.10		16.30	
Steam pressure in engine room, above atmosphere, pounds	75	77	146	144	175	179	205	205	255	258
Steam pressure in first receiver, above zero, pounds	34.5	35	60	62	71	75	81	82	102	100
Steam pressure in second receiver, above zero, pounds	10	15	17	18	21	19	22	20	24	30
Vacuum in condenser, inches	27	29	26	28	24.5	26	25	26.5	16	16

During the last runs of these trials the air pumps worked loose on their foundations causing a nozzle on the port air-pump suction to break, after which the vacuum fell to 24 inches, so that higher speeds were not obtained at that time. Observations were taken on the full-power speed trial as the measured mile was passed, giving the following results: Time of running against tide, 2 minutes 21.7 seconds; time of running with tide, 2 minutes 16.5 seconds; mean time, 2 minutes 19.1 seconds; mean speed, 25.88 knots; average revolutions, 358.06.

The official speed trial took place on November 28, 1900, when the vessel was run for two hours. During this trial the main engines worked very satisfactorily. No water was used on any bearing externally, except a small stream on the thrust bearings as a precautionary measure.

The boiler pressures showed very little fluctuation. There was no indication of foaming of boilers. There was very little vibration of main engines, either in athwartship or fore-and-aft direction, showing that the engines are well balanced and foundations strongly built. There was considerable vibration of bulkheads, causing breaks in the cylinder drain pipes, water-service pipes and disarrangement of the starboard engine counter gear. The temporary alterations in the starboard air-pump foundation proved to be insufficient, and the joints of the discharge pipe of pump and the shell of feed tank were broken.

The revolutions of the engines, accepted by the trial board as representing the performance of the vessel, were those made by the port engine. The records of readings of steam and vacuum gages indicate that the speed of the starboard engine was fully equal to that of the port. The mean revolutions of the port engine during the two hours' trial were 356.25 per minute, corresponding, according to the accepted standardization of the screws, to a speed of 25.79 knots per hour.

Indicator cards taken when running at 350 revolutions per minute, developed 3,275 I.H.P., corresponding to a speed of 25.45.

As the vessel was loaded to a displacement of 200 tons on trial instead of 165, as called for in the contract, this trial was looked upon as satisfactory, as the power developed would have given

U. S. Torpedo Boat *STOCKTON*, November 28, 1900.
Two-Hours' Contract Trial.

Hours.	Engine.		Steam pressure in pounds per square inch.			Opening of throttle valve, in tenths.	Vacuum in condenser, in inches of mercury.	Air pressure, in inches of water.
	Number of the counter.	Revolutions per minute.	At engines above the atmosphere.	In 1st receiver above a perfect vacuum.	In 2d receiver above a perfect vacuum.			
A. M.	**STARBOARD.**							
8·45	54,788	.....	245	97	25	10	24	
8·50	56,567	355.8	250	100	25	10	24	
8·55	58,302	347.0	258	102	26	10	23.5	
9·00	60,075	354.6	258	102	26	10	23.5	
9·05	61,858	356.6	258	102	26	10	23.5	
9·10	63,692	366.8	256	107	27	10	23.25	
9·15	65,502	362.0	256	107	27	10	23.25	
9·20	67,294	358.4	256	107	27	10	23.25	
	Mean.....	357.3	.....	.....	.....	.....	.....	
9·25	68,876		256	113	29	10	23.0	
9·30	.....		256	113	29	10	23.0	
9·35	72,150		256	113	29	10	23.0	
9·40	73,845		256	113	29	10	23.0	
9·45	75,375		256	113	29	10	23.0	
9·50	76,281		256	113	29	10	23.0	
10·00	78,509	Counter gear out of order.	256	113	29	10	23.0	
10·15	.....		251	111	29	10	23.0	
	Mean.....	.....	249.8	108.2	27.8	10	23.15	3.00 Approximately 3 inches.
	PORT.							
8·45	8,618	.....	246	97	29	10	21.5	
8·50	10,396	355.6	246	97	28	10	21.5	
8·55	12,148	350.4	241	95	28	10	21.0	
9·00	13,896	349.6	241	97	27	10	21.5	
9·05	15,670	354.8	244	97	27	10	21.0	
9·10	17,461	358.2	244	97	27	10	21.0	
9·15	19,250	357.6	254	101	29	10	20.5	
9·20	21,026	355.2	241	97	27	10	21.5	
9·25	22,819	358.6	248	98	28	10	21.0	
9·30	24,615	359.2	244	97	27	10	21.5	
9·35	26,386	354.2	241	98	28	10	21.5	
9·40	28,159	354.6	244	97	27	10	21.5	
9·45	29,938	355.8	244	99	27	10	21.5	
9·50	31,728	358.0	241	97	27	10	21.5	
9·55	33,495	353.4	241	98	27	10	21.5	
10·00	35,286	358.2	241	97	27	10	21.5	
10·05	37,079	358.6	240	97	27	10	21.5	
10·10	38,846	353.2	240	96	26	10	21.5	
10·15	40,617	354.2	240	96	26	10	21.7	
10·20	42,412	359.0	245	97	26	10	21.4	
10·25	44,187	355.0	254	98	28	10	21.0	
10·30	45,982	359.8	259	100	29	10	21.0	
10·35	47,773	358.2	253	100	29	10	20.5	
10·40	49,569	359.2	253	100	28	10	21.0	
10·45	51,368	359.8	251	95	27	10	21.0	
	Mean.....	356.5	247.3	97.8	28	10	21.3	3.00 Approximately 3 inches.

a speed in excess of the required speed of 26 knots, had the vessel been at the designed displacement. The vessel was, therefore, accepted.

The table on the preceding page shows the data collected on trial.

Stringham.—While running her contractor's preliminary trials in November last an accident happened to the torpedo boat *Stringham*, wrecking her starboard engine.

Three runs for speed were made over the measured mile at different times, and it was when about two-thirds over the course on the third run that the wrecking of the engine occurred.

Both castings, containing the four cylinders and valve chests, were damaged beyond repair. An examination after the accident showed that the bridge of the I.P. valve port, between the exhaust and the lower steam port, was broken out; the first L.P. cylinder valve port bridge, forming the upper flat of lower steam port, was broken, and the I.P. cylinder bottom was indented ¼ inch on the side next to the lower port opening.

The go-ahead eccentric and strap of L.P. cylinder was broken, and the feather securing eccentric to shaft was pulled out and seating in shaft enlarged.

The L P. eccentric rod was bent, and brasses broken. The L.P. link was bent. The I.P. valve was broken and L.P. valve chipped. Pieces of the I.P. valve port bridge were carried by the steam to the second L.P. valve and did the damage to this valve, exhaust bottom casting, eccentric rod, straps, eccentric and link.

The cause of the accident seems to be due, in the first instance, to the giving way of the I.P. valve port bridge. The flat surfaces of the these bridges are unstayed, and the valves sliding past them probably bite on the edges of these flats, due to their deflection from pressure, overheating, want of alignment or other unknown causes.

The *Stringham* returned to the works using her port engine, and her trial is postponed until spring.

AUSTRIA-HUNGARY.

Habsburg.—The battleship *Habsburg*, which was launched on the 9th September from the St. Marco Yard of the Stabili-

mento Tecnico Triestino, her first keel plate having been laid in March, 1899, is the first of a new class of battleships to be built for the Austro-Hungarian Navy. Austrians are very proud of the fact that only eighteen months elapsed between her commencement and her taking the water, and also that all the material, including the armor-plating, is being provided by Austro-Hungarian iron and steel works. The dimensions of the ship are as follows: Length, 354 feet; beam, 65 feet 9 inches; displacement, 8,340 tons; draught (extreme), 23 feet.

The hull is of Siemens-Martin soft steel, and, as far as possible, the use of wood has been dispensed with; the upper and superstructure decks have wood planking, but the other decks are covered with linoleum or corticine, whilst the inner surface of the double bottom is cemented.

Protection is afforded by an armor belt of chrome-nickel-steel 8.8 inches thick, reaching from 4 feet 4 inches below to 3 feet 6 inches above the water line, and extending some two-thirds the length of the ship. Above the belt and reaching to the main or battery deck is a citadel protected by 4-inch armor, shut in by 8-inch athwartship bulkheads rising from the lower armored deck, which is 2.3 inches thick forward of the casemate and 2.6 inches abaft. From the fore end of the armor belt to the ram the side is protected by 2-inch plating, which, in conjunction with the armor deck gives strong backing to the ram. A second armor deck 1.8 inches thick extends from the top of the belt, while the main deck between the fore-and-aft bulkheads is similarly protected, the combing of all the hatches being also armored. There are two barbettes for the heavy guns, one forward and one aft, protected by 8.4-inch armor, with ammunition tubes 7.2 inches thick; the secondary battery of 6-inch Q.F. guns will be mounted in double casemates, protected by 5.4-inch armor on the outer side and 3.5-inch on the inner side; the fore conning tower will be protected by 8-inch armor, decreasing to 6 inches on the communication tube, the after tower will have 4-inch armor, decreasing to 2 inches on the communication tube. All the armor will be of chrome-nickel-steel hardened by a special process, and be provided by the

great firm of Witkowitzk & Co., who have previously supplied the armor for the *Kaiserin und Königin Maria Theresia*, *Wien*, *Monarch*, *Buda-Pest*, and *Kaiser Karl VI;* and they have now quite established their reputation as armor makers and take rank with Krupp and the great English and American manufacturers.

The armament will consist of three 24-centimeter (9.4-inch) 40-caliber guns, two being carried in the fore barbette and one in the after; twelve 15-centimeter (5.9-inch) 40-caliber Q.F. guns, six each side mounted in double casemates, one over the other; ten 6-pounder and twelve 1-pounder Q.F. guns, with eight machine guns. The guns and ammunition hoists will be worked by either electricity or hand, while the ammunition tubes lead direct from the guns to the magazines, and it is calculated that by means of the electric hoists eight rounds a minute can be supplied. The axial height of the guns in the lower battery is 14 feet 8 inches above the water; in the upper battery, 21 feet 4 inches; and that of the barbette guns, 25 feet and 24 feet 4 inches fore and aft, respectively. There will be two submerged torpedo discharges for 18-inch Whitehead torpedoes. The heavy 24-centimeter guns are supplied by Krupp, but all the others are manufactured by the Skoda firm at Pilsen.

The ship will have twin screws, and the engines are to develop 11,900 I. H. P., which, with 136 revolutions, is to give a speed of 18.5 knots, steam being supplied by sixteen water-tube boilers on the Belleville system. The coal stowage will be 840 tons. Electricity will be used for lighting the ship, working the guns, barbettes, ammunition hoists, ventilators, etc., the current being supplied by six dynamos, producing three-phase currents and under armor protection. There are two other ships of the same type under construction, and a somewhat larger battleship, which will have a displacement of 10,000 tons.

Kaiser Karl VI.—The new first-class armored cruiser *Kaiser Karl VI* has lately completed her trials successfully. The engines developed 12,900 I.H.P., 100 H. P. in excess of the contract, while the mean speed maintained was 20.8 knots, or three-quarters of a knot in excess of requirements. Her dimensions are

as follows: Length, 373 feet 6 inches; beam, 57 feet 4 inches; displacement, 6,250 tons, with a draught of 20 feet 4 inches.

Protection is afforded by a partial belt of nickel-steel 8.8 inches thick at the water line, diminishing to 6.8 inches below, which extends some two-thirds the length of the ship; the barbettes for the two heavy guns and the two transverse bulkheads at each end of the belt, which extend up to the barbettes, having 8-inch armor. The armored deck has a thickness of 1.5 inches. The armament consists of two 24-centimeter (9.4-inch) 40-caliber guns, one in each barbette, forward and aft; eight 15-centimeter (5.9-inch) Q.F. 40-caliber Skoda guns, and twenty small Q.F. and machine guns, with four torpedo tubes. The ship has since proceeded to China, and is the flagship of Rear Admiral Graf von Montecuccoli, who commands the Austrian squadron in those waters, which consists of the first-class protected cruiser *Kaiserin und Königin Maria Theresia* and the torpedo cruiser *Zenta*.—"Mittheilungen aus dem Gebiete des Seewesens."

ENGLAND.

Warship Construction in 1900.—The total tonnage launched within a given period in any year affords a rough, although convenient, measure of the activity in the industry during such period, and the percentage of inaccuracy is probably not great when the work of the United Kingdom, or of a large district is concerned, but in a more limited area, or with one or two firms, the floating of a large ship included within the year "by a spurt," or delayed a day or two, may give a wrong impression if the standard is too arbitrarily enforced for purposes of comparison. This is exactly the case with the "output" of the royal dockyards during the year now closing. Only four small vessels have been launched, the total tonnage being but a fourteenth part of that of each of the two preceding years. But nothwithstanding this, the year has been one of great activity. The staff has been maintained at over 26,500, and the full vote of two and one-half millions for labor and four millions sterling for material will be more than earned—an experience which is not at present common to private naval work. Six battleships are being rap-

idly brought forward to the steam-trial stage—three will be ready within the next three or four months—while two battleships and two armored cruisers will be launched within the same period; already new ships of the same type are being prepared to be at once laid down on the berths when vacated. Thirty ships have been commissioned at the home ports, of which twelve were new vessels. Extensive overhauls were, or are, being carried out in the case of twenty-nine vessels, the cost running up to close upon £750,000.

With such a large fleet, an increasingly large proportion of dock-yard time must be devoted to this work of keeping the fleet in good fighting trim. In the case of many new ships and sixteen destroyers, steam trials were carried out, so that the record of actual work, apart from the mere statistics, was very considerable and satisfactory. There has been an absence of friction, notwithstanding the great body of workers, a condition largely due to the progressive policy of the Director of Dockyards, and here we may associate ourselves with the general feeling of congratulation in the service at the dignity of knighthood recently conferred upon Sir James Williamson. The changes effected this year in the administration of the dockyards included the appointment of an electrician, with high professional training, at Portsmouth, for the conduct and direction of all electrical work on ships, etc.; the general introduction of the rating of inspector in all trades, and an increase of pay to the following: Established and hired bricklayers and masons varying from 6d. to 2s. per week; established and hired ropemakers of 1s. per week; instructors to engineer students, allowance increased 8d. to 1s. per day.

But to return to the vessels launched, these may be dismissed in a few words, so far as the dockyard vessels are concerned. From Portsmouth there was floated out the *Pandora*, the latest of the "P" cruisers of 2,200 tons and 7,000 indicated horse-power to steam 20 knots. This vessel was not only constructed, but engined, at Portsmouth, and took a very long time to build. Indeed, she was inadverently included in our vessels launched last year, but the figures have since been carefully

amended, so that the comparisons may be accurately made. The other three vessels were sloops, launched at Sheerness; two, the *Shearwater* and *Vestal*, of 980 tons each, and the third, the *Espiegle*, of 1,070 tons. The last named is especially interesting, because she is being engined by the Wallsend Slipway and Engineering Co., who are new to naval work, although their general manager, Mr. Andrew Laing, has a long list of successes to his credit while he was at Fairfield. The boilers, too, are of the Babcock and Wilcox type. The same firm will similiarly equip another sloop, and a 12,500 indicated horsepower second-class cruiser, so that this steam generator, increasingly popular in the merchant service and in the United States, will have an extensive trial in our navy.

TABLE I.—FIGHTING VESSELS LAUNCHED.

	No.	Tons.	Indicated horse-power.	Value of ship completed.
In 1900.				
Dockyards	4	5,230	11,200	£394,600
Private yards (H.M.S.)	17	30,374	125,800	2,531,600
" (foreign)	8	25,827	42,750	1,925,000
Total in 1900	29	61,431	179,750	4,851,200
In 1899.				
Dockyards	6	66,900	78,000	4,901,100
Private yards (H.M.S.)	12	53,222	111,000	3,791,000
" (foreign)	16	47,170	124,000	3,767,000
Total in 1899	34	167,292	313,000	12,459,100
In 1898.				
Dockyards	8	70,955	84,800	4,441,000
Private yards (H.M.S.)	22	70,033	168,800	4,242,000
" (foreign)	18	52,365	144,250	3,480,000
Total in 1898	48	193,353	397,850	12,163,000

Nor do the British warships launched from private yards bulk large. Last year was an exceptionally busy year; the total for 1900 is the lowest for six years, as is shown on Table II. Two armored cruisers were launched—the *Aboukir*, from the Fairfield Works and the *Hogue* from the Barrow establishment of the Vickers Company, both of 12,000 tons and 21,000 indicated

horsepower, to steam 21 knots; and excepting two 980-ton sloops launched by Messrs. Laird, of Birkenhead, the remainder of the additions to the British navy floated were torpedo boat destroyers.

Messrs. Brown, of Clydebank, launched three—the *Thorn*, *Tiger* and *Vigilant*; Palmers Company three—*Myrmidon*, *Kangaroo* and *Syren*; Hawthorn, Leslie and Co., three—*Racehorse*, *Roebuck* and *Greyhound;* Laird Brothers, two — *Lively* and *Sprightly;* the Fairfield Company the *Ostrich*, and the Vickers Company the *Vixen*.

TABLE II.—ELEVEN YEARS' PRODUCTION OF BRITISH NAVY SHIPS.

Year.	Dockyard.		Private yard.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.
1890.....	8	22,520	13	42,475	21	64,995
1891.....	8	68,100	10	39,150	18	107,250
1892.....	9	50,450	13	90,750	22	141,200
1893.....	9	32,400	5	1,919	14	34,319
1894.....	8	26,700	19	4,825	27	31,525
1895.....	8	70,350	28	66,412	36	136,762
1896.....	9	70,970	26	36,515	35	107,485
1897.....	4	31,885	22	34,111	26	65,996
1898.....	8	70,955	22	70,033	30	140,988
1899.....	6	66,900	12	53,222	18	120,122
1900.....	4	5,230	17	30,374	21	35,604
Totals.....	81	516,460	187	469,786	268	986,236

But, as we shall presently show, the coming year will make up the average. Table I gives the tonnage, power and cost of the fighting vessels launched; we shall deal with the foreign ships later. Meanwhile, it may be noted that this years' total of vessels launched for the British Navy includes two 12,000-ton armored cruisers, one third-class cruiser, five sloops, and thirteen 30-knot torpedo-boat destroyers, the total tonnage of the 18 vessels being 35,604 tons, and the indicated horsepower 137,000, while the cost completed will be almost three million sterling. In 1899 there were eighteen vessels launched; but six of them were battleships and two armored cruisers, the remainder being small craft, so that the tonnage was 120,122 tons, and the cost

completed eight and three-quarter millions sterling; 1898 was also a battleship year, and the thirty vessels floated made up 140,988 tons, and represented an ultimate value as fighting ships of £6,683,000. In 1897 the total was 65,996 tons and over four millions sterling.

TABLE III.—THE PRODUCTION FROM EACH NAVAL YARD.

Yard.	1900.		1899.		1898.		Eleven years.	
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.
Portsmouth.....	1	2,200	1	15,000	1	15,000	17	153,835
Chatham.....	...	...	2	17,200	2	27,950	16	145,480
Devonport.....	...	...	2	30,000	2	15,085	20	97,585
Pembroke.....	...	...	1	4,700	1	11,000	11	94,615
Sheerness.....	3	3,030	...	...	2	1,920	18	25,945
Totals.....	4	5,230	6	66,900	8	70,955	82	517,460

But the first year of the new century will make up for this decrease in naval activity, which is only apparent. Indeed, the year of the millenary of the formation of the Navy will be appropriately enough a record in launches. Devonport, which, as shown in our next Table, did not launch any new vessels, will complete two battleships for commission, and will within two months launch a third, the 14,000-ton battleship *Montagu*, and in an adjoining berth there will be laid down, and probably launched, the 15,000-ton battleship *Queen*, while a second-class cruiser, the *Encounter*, of 5,800 tons, will be laid down also, the machinery of 12,500 indicated horsepower, to give 20½ knots, being entrusted to this dockyard, which has been specially successful with new engine work. Chatham, which also floated no vessel this year, while commissioning two battleships, will in February launch the *Albemarle*, and there will be laid down in the vacated berth the battleship *Prince of Wales;* and there will also be commenced the *Challenger*, sister ship to the *Encounter*, but to be fitted with Babcock and Wilcox boilers and machinery by the Wallsend Company. Pembroke, the third yard without a launch to credit this year, will launch the 14,100-ton 23-knot armored cruiser *Drake* and the 9,800-ton 23-knot armored cruiser *Essex;* while in

the place of the latter the *Cornwall*, another of the same class, will be laid down. Of this type, commonly called the "County" class, ten in all have been ordered. Another of them, the *Kent*, will be launched at Portsmouth, and in the vacant berth the *Suffolk* will be laid down. Sheerness will confine her attention to the sloops which police the fringes of the Empire.

It will thus be seen that two battleships and three large 23-knot armored cruisers, with a second-class protective deck, will be floated from the dockyards. From private works the number will be still more extensive—probably four battleships, three 14,100-ton 23-knot cruisers, and three other armored cruisers, so that this year's small total is not alarming. The battleships are the 14,000-ton 19-knot ships ordered in July last year—the *Duncan* and the *Cornwallis*, building at the Thames Iron Works, Blackwall; the *Exmouth*, being constructed in Messrs. Laird's graving dock at birkenhead; and the *Russell*, at Messrs. Palmer's at Jarrow-on-Tyne. The "mighty cruisers" *Leviathan*, *Good Hope* and *King Alfred*, were laid down in the autumn of 1899 at Clydebank, Fairfield and Barrow respectively—three well-known naval establishments. The only remaining of the six ships of the *Cressy* class to float is the *Euryalus*, at Vickers' Works at Barrow, and she will be launched in March. The first of the class—the *Cressy*—has passed through her trials; the *Sutlej*, from Clydebank, will follow in February; and there seems no reason why the others should not be completed within the contract time.

Of the ten cruisers of the County class, four are building in the dockyards, and to these we have referred. The Fairfield Company are building two of the others, the *Bedford* and *Donegal*, and the former will be launched next year. The London and Glasgow Company have the *Monmouth* and *Cumberland*, and the former will be floated next year; while Messrs. Beardmore and Co., who have taken over the old and famous establishment of Robert Napier, will build the *Berwick*, which, with one of the dockyard ships, will be fitted with engines and Niclausse boilers by Messrs. Humphrys, Tennant and Co. The other ship of the County class—the *Lancaster*—is to be built at

Elswick, and, along with one of the recently ordered dockyard ships, will be engined by Messrs. Hawthorn, Leslie and Co. With the exceptions named, all will have Belleville boilers. In Table IV we have tabulated the ships on hand. Of the battleships, three in the dockyards have been launched, and of the cruisers, three of the contract vessels are afloat.

TABLE IV.—BRITISH WARSHIPS IN PROCESS OF CONSTRUCTION.

	Battleships.		Armored cruisers.		Smaller craft.	
	No.	Tons.	No.	Tons.	No.	Tons.
Dockyards	7	103,000	5	53,300	6	15,880
Clyde	...	...	10	111,000	...	...
Thames	2	28,000	...	...	6	900
Tyne	1	14,000	1	9,800	...	...
Birkenhead	1	14,000	...	...	2	1,960
Barrow-in-Furness	...	...	3	38,100	...	...
Total	11	159,000	19	212,200	14	18,740

This list is a formidable one, especially when it is remembered that we have excluded vessels already completed although not tried, as well as three battleships and an armored cruiser, which should go through their trials before May next. We have thus a total of forty-four vessels of 389,940 tons, excluding eight or nine destroyers which also are nearly ready for trial. It is a list which at once shows the immense responsibilities undertaken by Sir William H. White, K. C. B., the Director of Naval Construction, who prepares the design of all these vessels. Their worth in fighting trim will probably be over twenty-five millions sterling.

The new work included in Table IV—that given out this year—includes for the dockyards two battleships, two armored cruisers (County class), two improved *Hermes* and two sloops, with a total displacement tonnage of 63,340 tons. From private firms there were ordered eight vessels of 39,820 tons, and machinery for fourteen vessels totalling 182,800 indicated horsepower. Two of the dockyard ships will be engined in the dockyards, so that the total power for the sixteen vessels is 196,700

indicated horsepower, and the tonnage 103,000 tons. The Clyde secured orders for 29,400 tons and 59,000 indicated horsepower; the Tyne for 9,800 tons and 57,900 indicated horsepower; the Thames for 620 tons and 50,900 indicated horsepower, and Belfast the engines for a battleship of 15,000 indicated horsepower.

Before proceeding to deal with the British warship steam trials of the year, it may be stated that the foreign warships launched included the Japanese battleship *Mikasa*, of 15,200 tons and 15,000 indicated horsepower, built by the Vickers Company at Barrow-in-Furness; the Japanese cruiser *Iwate*, of 9,750 tons and 14,500 indicated horsepower, built by Sir W. G. Armstrong, Whitworth & Co., at Elswick; a gunboat, the *Cidade de Manaos*, of 120 tons and 350 indicated horsepower, built by Messrs. Napier and Miller, Limited, Yoker; two gunboats for the French Navy, by Messrs. John I. Thornycroft & Co., Chiswick—the *Argus* and *Vigilante*, of 130 tons and 550 indicated horsepower, with a Japanese torpedo-boat destroyer, while Messrs. Yarrow have also contributed to the list, among others, two Dutch vessels, which gave very good results on trials, especially in view of their size.

The steam trials conducted during the year constitute some measure of the responsible work undertaken by Sir John Durston, K. C. B., the engineer-in-chief of the fleet; but, after all, the trials of new ships form only a small part of the work involved, *i. e.*, keeping the machinery, the vital part, of our ships in first-class order. But into this wide question we must not now enter. The number of warships tried during the year total thirty-one, and include almost every type. Taking first torpedo-boat destroyers, there were eighteen, and the results are set out in Table V.

It is gratifying to note generally that there are fewer breakdowns with these vessels in preliminary trials, the experience gained by contractors having enabled them in many cases to improve the details and the design without making any demand on the weight, which, owing to the speed desiderated, has to be kept to the irreducible limit. In service, too, the results are most satisfactory. The extreme economy in weight, in combi-

TABLE V.—TRIALS OF TORPEDO-BOAT DESTROYERS DURING THE YEAR 1900.

Name of firm and engineer.	Name of vessel.	Approximate displacement.	Type of boilers.	Grate area.	Tube surface.	Indicated horse-power.	Speed in knots.	Pounds of coal per I.H.P. per hour.
		Tons.		*Sq. ft.*	*Sq. ft.*			
John Brown and Co., Limited	*Brazen*	318	Clydebank. Normand.	224	12,000	6,539 6,734	29.565 29.418	2.5 .....
	Electra	319	"	224	12,000	466 6,567 6,751	12.963 29.557 29.583	1.61 2.32 .....
	Recruit	324	"	224	12,000	6,581 6,521	29.319 29.268	2.33 .....
	Thorn	342	"	224	12,652	6,540 6,455	30.174 30.063	2.34 .....
	Tiger	339	"	224	12,652	6,840 6,409	29.921 30.056	2.34 .....
	Vigilant	338	"	224	12,652	6,218 6,507	30.094 30.147	2.38 .....
J. I. Thornycroft and Co.	*Albatross*	383	Thornycroft.	252	16,020	718 7,732 7,678	14.330 31.552 31.500	1.97 2.26 .....
	Stag	306	"	193	12,072	406 5,204 5,561	13.081 30.156 30.345	2.25 2.307 .....
Earle's Shipbuilding and Engineering Co., Limited	*Bullfinch*	318	"	236	13,400	6,022	29.460	2.37
	Dove	322	"	236	13,400	5,802 6,012	29.250 29.363	2.75 .....
Fairfield Shipbuilding and Engineering Co.	*Falcon*	333	"	245	13,000	6,299 6,318	30.135 30.099	2.22 .....
	Ostrich	331	"	245	13,000	437 6,311 6,172	13.040 30.113 30.161	1.549 2.206 .....
Palmer's Shipbuilding Co.	*Petrel*	340	Reed.	258	13,784	6,444 9,320	30.097 30.054	2.300 .....
Doxford	*Lee*	322	Thornycroft.	237	13,520	6,558 6,265	30.110 30.078	2.535 .....
Hanna, Donald and Wilson	*Zephyr*	236	Reed.	238	9,936	3,885	27.171	.....
Hawthorn, Leslie and Co.	*Havock* (trial after reboilering.)	.....	Modified Yarrow.	150	8,512	419 Power trial only. 3,713	12.971	2.56 .....

In addition to the above vessels, the *Viper* and *Cobra*, fitted with turbine engines by the Parsons Marine Turbine Company, have run their official trials. These two vessels, built by Messrs. Hawthorn, Leslie and Co., and Messrs. Armstrong, Whitworth and Co., respectively, have boilers of the modified Yarrow type, made by Messrs. Hawthorn, Leslie and Co., with a grate area of about 276 square feet, and a tube surface of about 15,044 square feet per vessel.

nation with the great velocity, necessarily involve possibilities of frequent breakdowns; but, notwithstanding all this, the service reports are good.

Of this year's destroyers Messrs. John Brown and Co., Limited, supplied six for trials, but only the three later vessels exceeded the thirty knots. Two were tried by Messrs. Thornycroft, the *Albatross* steaming 31.55 knots, and the *Stag*, 30.34. Earles Company supplied two, which steamed respectively at 29.46 and 29.26 knots. Both of the Fairfield boats, and the one by the Palmers Company and Messrs. Doxford, exceeded the 30 knots, so that of the sixteen five were of 29 to 30 knots speed, eight were of 30 knots, one of 31½ knots, while the remaining two belong to the original set of 27-knot destroyers; the *Zephyr* has not yet seen service, but the *Havock* was in commission for some time.

The power results are no less interesting. It will be seen that the *Albatross* required only 7,732 indicated horsepower for 31.55 knots, while the *Stag*, also by Thornycroft, got her 30.15 knots with 5,204 indicated horsepower; and in the case of some of the other boats it varied up to 6,500, and even to 6,700 indicated horsepower. But weather and sea conditions may materially operate against a high speed being got for low power, and thus no arbitrary deductions should be made. Thus we find the *Vigilant* getting 30.09 knots one day with 6,218 indicated horsepower, and on another requiring 6,500 indicated horsepower for the same speed, while her exact duplicate, the *Tiger*, gets only 29.9 knots with 6,840 indicated horsepower. The coal consumption results do not call for much comment. Messrs. Brown's boats, which have a boiler embodying modifications suggested by Mr. Dunlop's experience of the Normand design, give almost a uniform consumption of 2¼ pounds per unit. The lowest result is that of the Fairfield-built *Ostrich*, 2.206 pounds, with the sister ship *Falcon* second, 2.22 pounds; but in previous years this has been excelled, a consumption of less than 2.1 having been got in two of Thornycroft's and one of Fairfield's boats. Without entering into any details, it may be said generally that the consumption is steadily being reduced. In only two cases this

year does it exceed 2.5 pounds—with the Earle Company's *Dove* (2.75 pounds) and Messrs. Doxford's *Lee* (2.535 pounds).

In addition to these sixteen torpedo-boat destroyers, fitted with the ordinary reciprocating engines, two similar vessels, the *Cobra* and *Viper*, have been tried, as recorded in a footnote to Table V; but there is no means of indicating the power developed by these vessels, or the rate of coal consumption per unit of power. Suffice it to say that they easily attained their guaranteed speed, 33.838 knots being recorded for the *Viper*, with a coal consumption well within the guarantee, while the *Cobra* did equally well.

Thirteen other British warships have been subjected to the usual machinery tests, and the results of these are set out in Table VI, given above. These vessels include the battleships *Glory* and *Albion*, belonging to the *Canopus* class; the *Cressy*, the first of six armored cruisers building by private companies; the *Spartiate*, the last of the eight cruisers of the *Diadem* type; the new Royal yacht *Victoria and Albert;* the *Pandora*, the last of eleven "P" third-class cruisers, the fourth river shallow-draught gunboat, the *Britomart*, and four sloops. These are all new ships. The third-class cruiser *Blanche* and the torpedo gunboat *Speedwell* have been fitted with water-tube boilers, and the results of their trials are included in the Table, along with those of the new ships.

The trials of these ships, it should be stated, are conducted with average stokers, the number of men required being drawn from the dockyard reserve, without reference to their previous experience of the water-tube boiler; so that the conditions approximate closely to those obtaining in actual service. We have always held that with trained stokers more economical results are obtained, and the data given in this Table go largely to prove this, while at the same time affording some assurance as to the future. Thus the sloops *Vestal* and *Rosario* are identical in engine, boilers and hull, and yet in corresponding trials the *Vestal* has proved quite 25 per cent. more economical as far as coal consumption is concerned. Thus at 340 horsepower the rate was, in the *Vestal* 1.56 pounds, and in the *Rosario* 2.27 pounds; at

TABLE VI.—RESULTS OF OFFICIAL STEAM TRIALS MADE DURING 1900 BY BRITISH WARSHIPS.

Name of ship.	Type.	Builders of ship.	Makers of machinery.	Length of ship in feet.	Displacement. Tons.	Type of boilers.	Heating surface.	Grate area.	Thirty hours' coal-consumption trial.			Thirty hours' coal-consumption trial at higher power.			Full-power trial.		
									Indicated horse-power.	Speed.	Coal per I.H.P. per hour.	Indicated horse-power.	Speed.	Coal per I.H.P. per hour.	Indicated horse-power.	Speed.	Coal per I.H.P. per hour.
Glory	Battleship	Laird	Laird	390	12,950	Belleville economizer	35,715	1,035	2,879	10.8 by log 10.447 by course	2.15	10,587	16.780 by course	1.7	13,747	18.124 by course	1.58
Albion	Battleship	Thames	Maudslay	390	12,950	Do.	33,511	1,072.5	2,772	11.2	2.17	...	...	...	...	...	...
Cressy	1st-class cruiser	Fairfield	Fairfield	440	12,000	Do.	51,577	1,650	4,731	13.89	1.87	16,270	20.596	1.79	2,124	20.7	1.93
Spartiate	Do.	Pembroke	Maudslay	435	11,000	Do.	47,300	1,390	3,834	12.3	1.83	...	Trial not yet completed				
Victoria and Albert	New Royal yacht	Do.	Humphrys	380	4,700	Do.	26,000	834	5,150*	15.4 by log* 16.3 course	1.988*	7,645*	18.47 by course*	1.88*	11,298	20.53	Not taken
Pandora	3d-class cruiser	Portsmouth yard	Portsmouth yard	305	2,200	Thornycroft	21,152	355.2	3,638	16.7	2.11	...	Trial not yet completed				
Blanche†	Do.	Pembroke	Earle's	220	1,580	Laird's water-tube	8,010	170.3	...	...	...	...	...	...	2,812	16.0 by log	Not taken
Speedwell‡	Torpedo gunboat	Devonport	Palmer	230	735	Reed	13,504	286.9	1,297	13.8 by log	1.58	...	...	...	6,062	20.8 by log	Do.
Britomart	Gunboat	Potter & Co.	Fawcett, Preston & Co.	180	700	Yarrow	2,002.2	80.5	668	11.2 by log	2.317	...	...	...	1,378	14.6	Do.
Rosario	Sloop	Sheerness	Keyham	180	980	Belleville economizer	4,000	136.8	338	8.4 by log	2.27	1,032	11.35	1.83	1,483	13.6	1.92
Condor	Do.	Do.	Thames	180	980	Do.	4,000	136.8	338	8.4	1.68	1,025	12	1.53	1,459	13.68	1.56
Vestal	Do.	Do.	Keyham	180	980	Do.	4,000	136 8	340	9.24	1.56	1,019	12.86	1 41	1,487	13.569	1.55
Shearwater	Do.	Do.	Thames	180	980	Do.	4,000	136.8	308	9.0	1.87	1,027	12.85	1.72	1,441	13.5	1.56

* These trials of the Royal yacht were exceptional, as they were of 48 hours' duration. † Reboilered and repaired.
‡ Reboilered and re-engined.

1,000 horsepower, 1.41 pounds against 1.83 pounds; and at full power—1,487 indicated horsepower—1.55 pounds against 1.92 pounds. It should be noted further that both ships have had their machinery from the Keyham establishment, which is doing very satisfactory work, and that the 1.41-pound consumption is the lowest recorded on warship trials in recent years. Indeed, the *Vestal* almost establishes a record, the former best performance having been with the 18,000-indicated horsepower cruiser *Amphitrite*, built and engined by the Vickers Company, at Barrow-in-Furness. The coal consumption of this cruiser at the respective trials was 1.54 pounds, 1.43 pounds and 1.57 pounds, and that of the 1,400-horsepower sloop *Vestal*, 1.56 pounds, 1.41 pounds and 1.55 pounds, so that practically speaking they are equal.

The *Glory*, while she has not done so well at low power as the three predecessors of the same class tried last year, has made a better performance at full power. But the data in the table will no doubt be studied with sufficient interest to obviate much detailed comment here. In the case of the *Glory*, it will be seen that the heating surface per unit of power is 2.6 square feet, which is ample, particularly as weight has had to be considered. In the *Cressy* the allowance is 2.46 square feet, and in this latter ship the power per ton of machinery is 11.7 indicated horsepower. In our new class of County cruisers, the heating surface is 2.23 square feet per indicated horsepower, while 12.3 indicated horsepower is to be developed per ton of machinery. Of the new ships tried this year, nine are fitted with the Belleville boiler of the economizer type; and the average consumption of these vessels on the low-power trials works out to 1.93 pounds per indicated horsepower. On the 30-hours' trial at higher powers—about 75 per cent. of the maximum—the mean consumption of the trials recorded is 1.69 pounds, while the full-power consumption average is 1.68 pounds. Last year, eight ships with the same type of boiler were tried, and the corresponding averages were—at low power 1.76 pounds, at higher powers 1.56 pounds, and at full power 1.65 pounds. It is not necessary to enter into the reasons why the low-power trials

show a higher coal consumption. The consumption trials of the *Victoria and Albert* were of 48 hours instead of 30 hours duration, and the results must be pronounced satisfactory.

The *Blanche* has been refitted with Laird's boilers, which are of the express small-tube type. In the case of the *Speedwell*, which has had new boilers and engines constructed by the Palmers Company, there has been a great increase in power and speed. The original power with the locomotive boilers was 3,500, and this was maintained, if for any time, with great difficulty; whereas, with the Reed water-tube boiler and the new engines, the power has become 6,062 indicated horsepower, and the speed has increased from about 19.5 to 20.8 knots. It is interesting to note that all the six ships of this class have been fitted with one or other of the several designs of water-tube boilers, and that now their speed approximates more closely to that anticipated when these torpedo catchers were originally built, twelve years ago. It only remains to be added that, in the case of the *Pandora* and *Spartiate*, the higher power trials have been postponed, while the *Albion* is at the present time undergoing the remainder of her contract tests; but the results in these cases will, no doubt, be as satisfactory as those of the vessels of their respective classes recorded in our Tables of this week and of twelve months ago.—"Engineering."

Sea-Speed Trials of Mediterranean Squadron.—The Admiralty have informed the Commander-in-Chief on the Mediterranean station (Vice-Admiral Sir John A. Fisher, K. C. B) that the results of the steam trials carried out by the ships of the Mediterranean squadron under his orders, between the 9th and 11th of June last, on the passage from Gibraltar to Aranci Bay, Sardinia, have been noted by their lordships as most satisfactory and as reflecting great credit on the engine-room staff of the vessels concerned. The Admiral has communicated this to the fleet in a general signal in which he states that he has great pleasure in conveying their lordships' message to the chief engineers of the squadron because it is thoroughly deserved.

The trial referred to was carried out at four-fifths power, the points between which the trial was run being six miles east of

Gibraltar to six miles north of Cape Figari (Sardinia)—a distance of 788 miles. The results were:

Ship.	Coal short on leaving Gibraltar.	Coal expended on trial.	Time occupied on trial.	Average speed per hour.
	Tons.	*Tons.*	*H. M.*	*Knots.*
Ocean	110	518	46 54	16.8
Isis	65	264	47 12	16.7
Dido	30	303	48 30	16.25
Renown	441	354.3	49 6	16.03
Venus	25	329.75	49 16	15.99
Cæsar	124.6	406.3	52 30	15
Victorious	809.35	455.3	52 36	14.98
Royal Sovereign	89	385	54 18	14.51
Royal Oak	95	509.5	55 10	14.3
Illustrious	116	469.9	55 20	14.25
Ramillies	98	337	55 22	14.22

Albion.—The new first-class battleship *Albion* has completed her thirty hours' trial at one-fifth power. The results were as follows: Draught of water, forward, 26 feet 6 inches, aft, 26 feet 6 inches; speed of ship, 11.2 knots; steam pressure in boilers, 241 pounds per square inch; vacuum in condensers, starboard, 27.1, port, 26.9; revolutions per minute, starboard, 66.4, port, 65.8; mean I.H.P., starboard, 1,379, port, 1,393, total, 2,772; consumption of coal, 2.17 pounds per I.H.P. per hour. The trials proved satisfactory.

Cressy.—The new armored cruiser *Cressy* (described on page 242, volume XII, of JOURNAL), having completed her three contractors' trials, left Plymouth on Tuesday morning, December 11, for progressive steam trials under Admiralty directions and supervision. The trials of the *Cressy* are being watched with considerable interest, as she is one of a new class of six armored vessels now under construction, and was the first to leave the contractors' hands. She was built and engined by the Fairfield Shipbuilding Company, and with the *Aboukir* (Fairfield), *Hogue* (Barrow) and *Sutlej* (Clydebank), was provided for in the Supplementary Naval Estimates of 1897–98, and the other two, the *Euryalus* (Barrow) and *Bacchante* (Clydebank), in the estimates of 1898–99. These cruisers are the longest that have been ordered since the *Powerful* and the *Terrible*. The engines are practically of the same type,

and each ship is supplied with thirty Belleville boilers, the *Cressy* class having economizers. The three trials have been most satisfactory, the only faults being due to unforeseen circumstances, owing to bad weather, and have nothing to do with the stability of the ship or the construction of her internal machinery. This is particularly noticeable with the boilers, which, although of the water-tube pattern, are said by the contractors to have worked more satisfactorily than in any other ship they have built, not a single hitch having occurred. The boilers are all of solid-drawn steel tubes, and special precautions have been taken against leakage at the joints.

The *Cressy* left Portsmouth for the first of her contractors' trials on November 23d. This was a thirty hours' run at one-fifth of her full power. A successful trial resulted, the ship making the Lizard, and athough she had a head wind there and back, she accomplished a speed of 13.89 knots at an indicated horsepower of 4,731, and averaged 74 revolutions port and starboard. She returned to Spithead on the following day, and, after coaling, left on Monday for a thirty hours' trial at four-fifths of her full power. The Start was reached with satisfactory results, but there the ship received the full force of a heavy gale from the southwest, and as she dipped her nose into the sea the propellers were lifted out of the water and the engines raced. This overheated the bearings considerably, and the speed had to be decreased and the trial stopped.

The vessel went into Plymouth Sound on Tuesday at midday, and, after readjusting the bearings, and coaling, she left on Thursday morning (November 29th) to again run the trial, having only completed seventeen hours of it. This was attended with exceedingly satisfactory results. The *Cressy* developed an average indicated horsepower of 16,800, and accomplished 20.5 knots, making 114 revolutions per minute. The Bellevue boilers were worked at natural draft, and when the result is compared with the speed at which the ship is designed (for 21 knots at 21,000 indicated horsepower), its satisfactory nature will be at once recognized. During this trial the contractors were successful in working in a progressive-speed trial for the

Admiralty. The vessel returned to Plymouth Sound on the Friday and remained there until Tuesday, December 4th, when, after coaling, she left for a final trial of eight hours at full power over the 23-miles deep-sea course between Rame Head and Dodman Point. In consequence of a thick fog and bad weather generally, this trial was postponed until the next morning. It was reported previously that there was a breakdown on Tuesday evening, while, as a matter of fact the ship was in the Sound nearly all day and has, so far, not had any breakdown. Bad weather again prevented the trial being started on Wednesday morning, but she left later in the day. An hour or so after commencing the run the gale increased in violence, and as there was again danger of the bearings becoming heated the trial was stopped. Some bearings had become heated, and this was put right while the ship cruised about all night at seven knots between Start Point and the Eddystone. This continued until 7·30 on Thursday morning, when, the sea having moderated, the eight hours' trial was again commenced. With 122 revolutions an indicated horsepower of 21,200 was developed, and a speed of 20.79 knots was maintained. Judged by figures, this trial does not appear so satisfactory as the previous one at four-fifths of her power. Both the Admiralty officials and the contractors' representatives were, however, completely satisfied, as it was estimated that if the trial had taken place in fine weather instead of in a gale she would have exceeded the speed for which she was built. On this trial the contractors endeavored to maintain the full-speed run as required by the Admiralty, but were obliged to abandon it in consequence of the weather, and to be satisfied with their own full-power trial.

During her eight hours' full-power trial, her engines worked so uniformly that the I.H.P. was 10,473 starboard and 10,767 port, but the difference between the power of the two engines at the preceding thirty hours' trial at four-fifths power was only 12, the I.H.P. starboard being 8,141, and port, 8,129, while the revolutions on both sides were identical, being 114.6 starboard and port. It is not customary to record the coal consumption at a full-power run, but it was taken in the case of the *Cressy*, and

worked out at 1.93 per unit of power per hour, but at the four-fifths power run it was only 1.79.

With this run the contractors completed their series of trials, and, in fact, would have finished with this ship altogether, but they are now being employed by the Admiralty to run the first Admiralty trial. The *Cressy* having taken on board 900 tons of coal, left Plymouth on Tuesday for the 18 knots and full-power Admiralty progressive speed trials.

The trials of the *Aboukir*, the other ship of the same class being built by the Fairfield Company, will take place in March next.—"Naval and Military Record" and "Journal R. U. S. I."

Encounter.—The engineering department at Davonport Dock Yard has commenced the manufacture of a set of eighteen water-tube boilers of the Belleville type and two sets of triple-expansion engines for the cruiser *Encounter*, which is to be laid down at that yard.

Hermes.—After a cruise of only thirteen months, the cruiser *Hermes*, paid off at Devonport on December 8. She was commissioned for the first time in October, 1899, and left a few weeks later for the North American Station. Serious boiler defects were discovered, which rendered the ship useless at one time, and for about six months the engineering staff, assisted by the officials of the Bermuda Dockyard, were engaged in refitting her with a new set of Belleville boilers sent out from England.

Twelve out of the eighteen boilers were made efficient, and with these the vessel came home, and as far as can be ascertained they are still in a satisfactory state.

(Full description of this vessel will be found in the JOURNAL, Vol. X, p. 545; Vol. XI, pp. 789 and 794; Vol. XII, p. 246.)

Hyacinth.—The *Hyacinth*, cruiser (data of vessel and previous trials will be found in JOURNAL, Vol. X, pp. 1190 and 1193; Vol. XII, pp. 246–248,) returned to Plymouth on November 30, 1900, on completion of a steam trial in the Channel. She made four runs over the 23-mile course off the Cornish coast, and easily maintained a mean speed of eighteen knots. The results, both in the engine and boiler rooms, were highly

satisfactory, the coal consumption record comparing very favorably with that of other trials under similar conditions.

The *Hyacinth*, cruiser, left Plymouth on Monday morning, December 2, for a four-hours' full-power trial. She had no difficulty in maintaining a mean indicated horsepower of 10,000, but, as with this enginepower she only recorded a speed of 19.7 knots, the results were not altogether satisfactory. A heavy sea was running in the Channel, and as the vessel has not been docked for some time these causes, no doubt, were responsible for the low rate of speed.—"Naval and Military Record."

Lee.—The new torpedo-boat destroyer *Lee*, built by Messrs. Doxford & Sons, of Sunderland, has undergone a successful three-hours' official coal-consumption trial. On the six runs on the measured mile her average speed was 29.9 knots, but for the whole of the three hours the speed was 30.11 knots. The official results were as under: Draught of water, forward, 5 feet 4½ inches, aft, 8 feet 10¾ inches; steam pressure in boilers, 249 pounds per square inch; vacuum in condensers, starboard, 23.3, port, 23.1; revolutions per minute, starboard, 380.7, port, 380.4; mean I.H.P., starboard, 3,382, port, 3,193; total I.H.P., 6,575.—"Journal R. U. S. I."

Minerva.—The first of a series of trials to test the relative endurance and cost of cylindrical and Belleville boilers ended at Portsmouth, January 17, on the return of the *Minerva* cruiser, Captain C. H. Cochran. She was required to steam for thirty hours at 2,000 indicated horsepower, but at the end of the twenty-fifth hour the Parliamentary Committee on Boilers were satisfied with the results, and the ship made for Portsmouth. The mean speed during the trial was 12 knots, which was produced with 2,133 indicated horsepower, and the coal and water consumption respectively was 2.15 pounds and 19.04 pounds per unit of power per hour. The *Minerva*, which is fitted with cylindrical boilers, at the close of the trial went into harbor to have her tubes cleaned before going on the next run.—"Engineering."

Mutine.—The *Mutine*, a new sloop-of-war, built to the order of the Admiralty by Messrs. Laird Bros., Birkenhead, put into

Spithead on December 19 last, in consequence of an explosion having occurred on board. The vessel was on her passage from Birkenhead to Sheerness, in charge of a navigating party from the latter port, the contractors being in charge of the boilers and machinery. As the vessel was steaming up the channel, and when not far from Plymouth, a tube of a Belleville boiler burst, severely injuring two men, one of whom died the next day.

Pandora.—The new third-class cruiser *Pandora*, which was built and engined in Portsmouth Dockyard, has completed a thirty-hours' trial at half power. She developed 1,789 I.H.P., starboard, and 1,849, port, or a collective I.H.P. of 3,638, and with 196 revolutions, starboard, and 194.4, port, she averaged a speed of 16 7 knots, with a coal consumption of 2.11 pounds per unit of power per hour.—"Journal R. U. S. I."

The "P" Class of Cruisers.—The *Pandora*, cruiser, has been out at last for her trials. On the thirty hours, "half power," with a mean of 195 revolutions, she made 3,638 mean I.H.P. and a mean speed of 16.7 knots. Coal consumption was 2.11 pounds per I.H.P. She is the last vessel of the "P" class, the corresponding trials of which were as follows:

	Hours.	*I.H.P.*	*Knots.*
Pelorus	60	4,277	17.3
Proserpine	60	3,615	17
Pactolus	30	3,631	16.6
Pegasus	30	3,698	17.3
Perseus	30	(Not available.)	
Pomone	30	3,604	16.5
Prometheus	30	3,556	17.5
Pyramus	...	3,605	17.5
Pioneer (foul bottom)	...	3,665	16.3
Psyche	...	3,647	16.8
Pandora	...	3,638	16.7

The *Proserpine* has Thornycroft boilers, the *Pomone* Blechynden; all the others, Bellevilles.—"The Engineer."

Racehorse.—H. M. S. *Racehorse* was launched on November 8, from the Hebburn shipbuilding yard on the east coast of England. The *Racehorse* is one of three similar vessels now under construction, and is one of the latest type of torpedo-boat destroyers. Her length is 210 feet; breadth, 21 feet; depth, 12

feet 6 inches, with a displacement of 316 tons. The armament consists of one 12-pounder and five 6-pounder quick-firing guns, and two deck torpedo tubes.—" Marine Engineering."

Shearwater.—The new sloop *Shearwater* (described on page 564, Vol. XII, of JOURNAL) has completed her final full-speed trial satisfactorily. The results were as follows: Draught of water, forward, 10 feet, aft, 13 feet; pressure of steam, in boilers, 226.8 pounds, on engines, 200.8 pounds; vacuum, 23.5 inches; revolutions, 194.2 per minute; I.H.P., high, 430, intermediate, 461.3, low, 541; total, I.H.P., 1,432.3. The coal consumption was 1.57 pounds per I.H.P. per hour.—"Journal, R. U. S. I."

Spartiate.—The first trial of the *Spartiate* at one-fifth power was described in Vol. XII, page 1,103 of JOURNAL. The second trial for thirty houre at four-fifths the total power had to be brought to a premature conclusion, owing to the overheating of the bearings and the fusion of the white metal. The damage has not yet been made good.—" Journal R. U. S. I."

Gun Accident on Board the Thunderer.—While the battleship *Thunderer* was on her way from Pembroke Dock to Devonport to join the Reserve Squadron, an accident occurred to two of her guns, the cause of which is so far unexplained. The vessel left Pembroke about 9 A. M., and when she was off Milford Haven a target was dropped for firing practice, the 10-inch breech-loading turret guns being used. A projectile had been placed in one of the guns and the electric current turned on, when there was an explosion quite different from that which usually accompanies the discharge of a projectile. Nothing came out of the gun except a few fragments of the projectile, which were thrown some distance from the ship. The base plate of the projectile was left in the gun, as well as a portion of the frame, and when the plate was afterwards removed the pressure of the gas left in the gun caused a portion of the projectile to be expelled with some force from the breech end of the gun. When the second gun was fired, a hole between two inches and three inches in diameter was blown through the projectile, the outer part, together with the base plate, being left in the gun. In this case the base plate was separated from the rest of the

projectile. Such a thing is believed never to have occurred in any ship before. The only explanation so far suggested is, either that the powder in the projectile was damp, or that there was a quantity of water in the guns. A cast will be made of the inside of each gun to ascertain whether either has been damaged. So far as can be seen from the outside, both guns are sound.—"Journal R. U. S. I."

Vestal.—The new sloop *Vestal* (described in Vol. XII, p. 564, of JOURNAL) has completed her second special trial satisfactorily. The trial lasted 57 hours, and the following results were reported: Draught of water, forward, 10 feet 4½ inches, aft, 13 feet; vacuum, 27.62 inches; revolutions, 163.2; I.H.P., high, 189.6, intermediate, 256.4, low, 288.9, total I.H.P., 734.9; coal consumption, 1.86 pounds per I.H.P. per hour; speed, 11 knots. The trial, which was of a satisfactory character, was made at half full power, the object being to ascertain the coal consumption per I.H.P. per hour on a run with 35 tons of Welsh steam coal, such as is supplied to ships on ordinary service. The whole of the boiler power—four Belleville boilers with economizers—was used. The previous trial was made with hand-picked Welsh coal, when the consumption averaged 1.82 pounds per I.H.P. per hour. The weather, however, was more favorable at the trial with ordinary coal than at the hand picked coal test.—"Journal R. U. S. I."

Viper.*—The recent trials of H. M. S. *Viper*, which is the first torpedo-boat destroyer to be fitted with steam turbine propelling machinery, have attracted much attention, and as the results, which have been published from time to time in your columns, have proved entirely successful, the specified speed being greatly exceeded, and all previous records (including those of the *Turbinia*) having been broken, perhaps I may be allowed to discuss certain points in connection with the figures attained which are of considerable interest and importance. We had not ourselves thought of making a strict comparison between the coal consumption of the *Viper* at any particular speed with that of other vessels of similar tonnage, as she differs in essential particulars

* Letter from Charles A. Parsons to the "London Times."

from all other vessels, and such a comparison would be entirely misleading unless accompanied by a full statement of the principal features of the vessels to be compared, with their necessary bearing upon the results. But, as other persons have thought well to make an unqualified comparison, I now propose to briefly place the case on a sound footing, and I may add that the comparison is interesting and instructive, especially to those whose business it is to design or to use fast vessels.

The trials of the *Viper* have been somewhat more elaborate than usual for torpedo-boat destroyers, though they do not by any means as yet cover the whole of the ground. They have included a coal consumption trial of the contract speed of 31 knots, the mean speed during the three hours being 31.118 knots, and the coal consumption, as determined from the usual hull resistance experiments, 2.38 pounds per indicated horsepower per hour, the contract being not to exceed 2.5 pounds per indicated horsepower. The power required for this speed is about two-thirds of the maximum for which the engines and boilers were designed, the maximum being upward of 12,300 indicated horsepower, which power has been realized on preliminary, but official, full-power contractors' trials, the maximum mean speed then reached 36.858 knots.

The second official trial was a three-hours' coal-consumption trial, with the air pressure limited to $3\frac{1}{2}$ inches, and carrying the full weights as determined by the previous trial under the usual Admiralty conditions.

A mean speed of 33.838 knots was maintained with about four-fifths of the maximum power, the coal consumption being at the rate of 2.49 pounds per indicated horsepower per hour.

The third official trial was the usual twelve-hours' coal-consumption trial at cruising speed.

In recent years the stipulated speed on this trial has been increased from thirteen knots to fifteen knots (this I mention, as the coal consumption of the *Viper* at thirteen knots is only about two-thirds of that at fifteen knots). The ascertained coal consumption of the *Viper* on this trial was at the mean rate of 27 hundred weight per hour. It should be mentioned, however,

that H. M. S. *Cobra*, the second fastest ship afloat, with the same sized turbine engines and similar in every respect to the *Viper*, but loaded to service conditions and having a displacement of 442 tons, or about 60 tons greater than the *Viper*, consumed on her official 15-knot trial 24.58 hundred weight per hour. In her case the port engines only were used, the starboard engines being dragged round by the propellers, and it is probable that the *Viper* with her less displacement would, when using one set of engines only, burn less coal than the *Cobra*. As, however, it would be instructive to ascertain this result definitely, it is probable that this test will be made at an early date.

Now to the case in point.

A comparison has been made of the coal consumption of the *Viper* and the *Albatross* at a speed of about thirty-one knots.

It so happens that the two vessels have the same displacement, and it is tacitly assumed in the accounts that the horsepower necessary to drive the two vessels is the same, which is by no means the case, for the following reasons: In the case of the *Viper* all the underwater fittings, such as rudder, the shafts and brackets for carrying the propeller shafts, the propeller blades and bosses, and so forth, have all been designed to stand the highest speed of over thirty-six knots, and are of considerably larger and heavier scantlings than usual, and in consequence offer increased resistance to their passage through the water. So much for the shipbuilder's point of view.

Now for the engineer's side of the question. To give to the *Viper* her five extra knots, and to absorb usefully the relatively enormous horsepower developed by her engines, her propellers have extra width of blade and a much greater total blade area than that of the *Albatross*, whose maximum horsepower is only about two-thirds of the *Viper's*. This greater blade area is not only useless at lower speeds, but involves a positive waste of power at such speeds, owing to the increased skin friction. If, on the other hand, the *Viper's* propellers had been designed for a maximum speed of only 32 knots (the contract speed of the *Albatross*), they would undoubtedly have given superior results at about 31 knots.

Then as regards the turbine engines themselves. At the speed of 31 knots the *Viper's* engines are working at only two-thirds full power, and are necessarily less economical than if they had been smaller and designed for the power required for 32 knots.

Then there are the boilers to compare—a very important item in the case.

The *Viper* has the well-known Yarrow boilers of simple construction and of great durability and power, but is without any refinements external to the boiler for attaining the highest possible economy of coal—refinements, be it said, of somewhat doubtful advantage in ordinary service. The *Albatross*, on the other hand, has the well-known Thornycroft boiler ; she has also feed-water heaters to increase the efficiency, and also compressed air jets for promoting more complete combustion of the furnace gases before coming in contact with the tubes.

These are now the factors of chief importance bearing upon the question of the relative coal consumptions of the turbine engines and reciprocating engines in the respective vessels.

On the one hand we have the larger engines, greater propeller-blade area, heavier underwater fittings, greater hull resistance, powerful, durable boilers of simple construction without external adjuncts for attaining the highest economy on trial, the vessel being capable of a speed of 5 knots in excess of any vessel propelled by reciprocating engines.

On the other hand, we have a vessel whose engines and propellers are capable of developing only about two-thirds of the horsepower of the other, designed for a much lower speed—in fact, about that at which the comparison is taken—and having boilers of noted efficiency in coal, assisted by somewhat complex additions for further increasing the economy.

That the reduction in the coal consumption attributable to the aggregate of these important differences greatly exceeds the difference between the coal consumption of the *Viper* and the *Albatross* at about 31 knots speed there can be no question whatever, and there cannot be the slightest doubt that in every class of vessel (excepting only very small or slow vessels) it will be

found that the turbine system of propulsion will give superior results over the reciprocating engine as regards coal consumption.

In the *Viper*, in spite of these losses of power at lower speeds which we have described, and incurred in order to reach the record speeds attained (speeds only attainable by turbine machinery), without any special effort to attain economy, even so, her coal consumption per horsepower realized is very little in excess of the best, and less than that of many of the 30-knot destroyers.

In the specifications of most admiralties for torpedo boats and destroyers the question of speed is placed in the forepart and enforced under heavy penalties, culminating with the option of complete rejection of the vessel should the deficit reach more two to three knots below that contracted for. The coal consumption is relatively placed in the background.

This being so, the designers of the *Viper* may be pardoned if they have made every effort to attain the highest possible speed and have not given sufficient consideration to the question of obtaining the utmost economy of fuel of which turbines are capable; but in this, their first destroyer, they can, at least, claim to have beaten all records of speed by a long interval, and in their future ships they will be able to show by how much they can beat all records as to economy in coal.

FRANCE.

Amiral-Duperré.—The first-class battleship *Amiral-Duperré* is to be shortly placed in the Second Category of the Reserve, when she will undergo a complete refit at a cost of 1,500,000 francs (£60,000); the repairs and alterations to be carried out include: 1. New boilers. 2. General repair of hull and engines. 3. The substitution of four 6.4-inch Q.F. guns in a central casemate for the midships 13.3 inch gun in its barbette.—"Journal R. U. S. I."

Charlemagne.—The cruiser *Charlemagne* has left her dock. Her screw had been carried away and she has been put on the road again not to be laid up. After the repair to her screw she will be taken back to her dock to have it put in place. She still

has her two screws, and therefore can follow the squadron in its maneuvers without great difficulty, while a vessel with two screws deprived of one of them would find herself at a great disadvantage for the purpose of maneuvering. Here is a striking proof of the utility of three screws, which we have been the only ones to adopt for our large warships of recent date. In ordinary times, when the three screws are in action they offer great advantages in operation while at anchor, while getting under way and also in squadron maneuvers, and in rank and file, because the speed of the ship can be varied so frequently, so easily and so quickly.—"Le Yacht."

Gustave Zédé.—The Minister of Marine visited the submarine boat *Gustave Zédé* at Cherbourg when the combined Mediterranean and Channel Squadrons were lying at Cherbourg. He went on board her accompanied by Rear Admiral Bienaimé, Chief of the Staff at the Ministry of Marine, and other officers. The boat took nine minutes to submerge, but it is said it can be done more quickly when she is in motion. When submerged only a flag at each end and the tube of the periscope in the center were left visible. The *Gustave Zédé* made the round of the ships in the roadstead, being kept at a uniform depth during the run, the speed being 9 knots. During the run one torpedo was discharged. Before returning to the harbor, owing to the supply of oxygen being exhausted, the boat had to come to the surface; but on the whole the Minister expressed himself pleased with the performance. It is reported that the Minister of Marine, as the result of his trip, has decided to appoint a committee to consider the whole question of submarine or submergible boats.—"Journal R. U. S. I."

Kléber.—One set of the engines for the French cruiser *Kléber* were exhibited at Paris by the makers, Schneider & Co., Le Creusot. The *Kléber* is fitted with three screws and three independent sets of engines, with 17,000 collective I.H.P. Each set consists of three cylinders. The valves are all of the piston type. The high-pressure has one, the intermediate-pressure cylinder two, and the low-pressure cylinder three. The valve-gear is Stephenson's. The cylinders are 34 inches, 48 inches

and 77 inches in diameter, with 31½ inches stroke. At full speed the engines make 150 revolutions per minute. Steam is supplied by twenty Niclausse boilers, divided into four groups, two forward and two aft of the engine room. The pressure is 256 pounds per square inch. The total grate surface is 1,100 square feet; the total heating surface, 35,500 square feet. The total weight of engines, boilers, &c., is 1,275 tons, water in the boilers included, which gives a total weight of 174 pounds per I.H.P. The engines weigh 663 tons, and the boilers 612 tons. The total heating surface, omitting fractions, is 2 square feet per I.H.P.—"The Engineer."

Montcalm.—The *Montcalm* is 453 feet in length, 63 feet 8 inches in beam, draws 24 feet 7 inches, and at this draught displaces 9,517 tons. She is propelled by triple-screw engines of 19,600 horsepower at a maximum speed of 21 knots per hour. Her normal coal capacity is 1,020 tons and her total bunker capacity is 1,600 tons, and in these totals is included a certain amount of liquid fuel. The motive power is thoroughly up to date, the steam being furnished by batteries of Normand-Sigaudy water-tube boilers. The vessel is protected at the waterline by a practically complete belt of Harvey steel, which is 6 inches in thickness amidships and tapers to 3¼ inches in thickness at the bow and stern. For a little over a quarter of her length, commencing from the bow and running aft, the waterline belt is carried up to the main deck. Associated with the belt is a 2-inch armored deck, and the various gun positions of the casemate or turret type are protected by Harvey armor which varies in thickness from 3¼ to 8 inches. There are two submerged torpedo-tube dischargers. The armament consists of two 7.6-inch breech-loading rifles carried in two turrets, one forward and one aft on the center line of the vessel, both upon the spar deck; eight 6.4 inch rapid-fire guns mounted in sponsons on the broadside on the main deck, the two forward and after guns being capable respectively of deadahead and deadastern fire; four 3.9-inch rapid-fire guns, mounted in broadside on the spar deck; and sixteen 3-pounders and six 1-pounders which are carried in convenient

positions throughout the superstructure, the bridges and the fighting tops.

The *Montcalm* is modeled above the waterline with the characteristic tumble-home that is seen in so many of the French vessels; but we miss in her the exaggerated ram bow which one has associated with the French cruisers of former years. The total complement of the ship is 612 officers and men, and it is probable that the great length of the vessel will enable the crew to be very comfortably berthed.—"Marine Journal."

Morse and Narval.—In the "Moniteur de la Flotte," M. Rosseau devotes an article to submarine and submersible boats in relation to the recent trials at Cherbourg. He says that the trials did not throw any new light upon these engines of war, but that they had the merit of bringing the two types of boats into direct comparison, and that the opinion of officers who had been in command of them was unanimous. They all indicated their preference for the submarine boat properly so-called, having evidently some distrust of the submersible. M. Rousseau, however, points out that the *Morse* represents a type of boat more or less established, and that the submersible *Narval* is of a new class altogether. He remarks that the trials must not be interrupted of a type of boat which will have the advantage of being offensive. He has been on board the *Morse*, and says that she navigates with perfect ease below water, that those in her are able to discern by means of the periscope what is going on upon the surface, and that torpedoes are discharged with an accuracy and certainty which might be the envy of officers of ordinary torpedo boats. It appears that the periscope can be employed up to a depth of about twenty feet below the surface, and, according to M. Rousseau, it is quite adequate to prevent collisions, and, being turned around, enables those below to scan the whole horizon. It has been suggested that the instrument would be valueless except in smooth water, but the writer cited asserts that during the Cherbourg experiments the sea was very rough and that the appliance gave, nevertheless, a very clear view.

At a greater depth than twenty feet the course of the *Morse* is

directed by the compass. The plunge is effected by suppressing her floatibility by admitting water into special chambers, and there is equilibrium so that the descent is made in the horizontal position, and the required level is maintained by lateral wings or rudders, to the movement of which the boat is very sensitive. The class of boat thus described is available purely for local defences, but the *Narval*, the system of which is described by M. Rousseau, could be employed in offensive operations. He says that the advantages of the submersible system would be incontestable, but that certain problems have arisen of which the solution has not yet been altogether realized. Larger water chambers and more powerful pumps are required for the plunging and raising of the boat. The steam not used during surface navigation must be condensed. These difficulties, combined with the necessity of coupling the electric mechanism with the driving apparatus, make it impossible to plunge the boat within less than 17 or 18 minutes. The period will be reduced to 10 minutes in the *Silure*, *Triton*, *Sirène* and *Espadon*, but it will still be too long, and in an actual encounter would leave the boat helpless before her adversary. The belief of M. Rousseau, however, is that the type of the submersible is perfectible, and that the difficulties will be overcome.—" Engineering."

Neptune.—With the new year will also commence work on the first-class battleship *Neptune*, lately placed in the Second Category of the Reserve for overhaul. The estimated cost of her repairs will also amount to 1,500,000 francs (£60,000). Belleville boilers are to be substituted for the cylindrical ones, the engines are to be modified for working at high pressure with the new boilers, and a good deal of the superstructure is to be removed.—"Journal R. U. S. I."

Saint Louis.—The first-class battleship *Saint Louis*, flagship of the Mediterranean Squadron, while being docked recently, at Toulon, had a narrow escape of falling over in the dock. The water was partly pumped out when a sudden crack was heard under the starboard quarter, and it was found that several of the shores had given way and the vessel took a serious list to starboard. Orders were promptly given to let the water into the

dock at once, by all the inlets, and the *Saint Louis* righted, and was soon afloat without damage. Had the dock been dry at the time it is probable she would have fallen right over.—"Journal R. U. S. I."

Submarine Boats.—The number of submarine boats actually under construction at Cherbourg is six, which include the two submarines, properly so-called, the *Francais* and *Algérien*, and the four submergible boats of the *Narval* type, the *Sirène*, *Triton*, *Silure* and *Espadon;* the estimates for 1901 make provision for the construction of two more, so that with the *Morse* and *Narval*, ten of these little vessels will have been built at this yard.—"Journal, R. U. S. I."

Trombe.—The French torpedo boat *Trombe*, built in Nantes, went out for a preliminary trial on September 29th from Lorient and struck a rock at Port Melite. Going at a rate of 23 knots per hour, the shock was very violent. The boat was ripped up for about 20 feet of its length as far as the watertight bulkhead, and one man in the forecastle was severely wounded. The *Trombe* was cleared and assisted by a fishing boat. As no damage appeared abaft of the watertight bulkhead, she could be returned to the harbor under her own steam with the assistance of some steam tugs. As the *Trombe* had not yet been accepted by the Navy Department, the damage will have to be borne by the builders.—"Mit. Geb. Seew."

GERMANY.

Amazone.—On 6th October was launched from the Germania Yard, Kiel, the new small cruiser "F," the christening ceremony being performed by H.R.H. the Hereditary Grand Duchess of Baden, the vessel receiving the name of *Amazone*. Her dimensions are as follows: Length, 325 feet; beam, 36 feet 6 inches; displacement, 2,645 tons on a draught of 16 feet 3 inches; the hull will be wood planked and coppered. The boilers will be water tube on a system compounded from the Thornycroft and Schultz boilers, devised at the Germania Yard. There will be a 2-inch armor deck with a cofferdam filled with cork running round the inner part of the ship at the water line. Great pains

have been taken to make the mess deck for the men as roomy and airy as possible, the ship being intended for service in the tropics. The coal stowage will be 500 tons. For so small a vessel the armament is a powerful one, viz: ten 10.5-centimeter (4.1-inch), fourteen 1½-pounders, eight machine guns, two above-water broadside torpedo-tubes, and one underwater in the stem. —"Journal R. U. S. I."

Freya.—The new second-class cruiser *Freya* has commenced her trials. The ship is fitted with French water-tube boilers on the Niclausse system, but the first full-speed trial was not very successful, the ship only making 18 knots instead of the 19 knots contracted for. The tubes seem to have become choked very rapidly and in other ways the boilers have proved themselves unsatisfactory, and no further experiments are to be made with them. —"Journal, R. U. S. I."

(For description of first trial and data of vessel see Vol. XI, pages 255 and 1,110, of JOURNAL.)

Freya and Gazelle.—The big cruiser *Freya* and the small cruiser *Gazelle* have been put in commission for their trial trips. It will be remembered the *Freya* has Niclausse boilers, while the *Victoria Louise* and the *Hertha* have Belleville boilers, and the *Hansa* and *Vineta* have Durr. The intention was to gather in this manner experience as to which of the three systems of boilers would be most suitable for warships. These tests proved unfavorable for the Niclausse boilers, this system not being successful. At the first trials of the *Freya*, it appeared that the ship could only make a speed of 18 knots, while an average speed of 19 knots was anticipated. In addition, the wear of the tubes was augmented by the alkalis and salts of the water that were soon deposited in the tubes. The *Freya* had considerable leakages in the boilers and had to be placed out of commission for extensive repairs. Just as bad were the experiences with the small cruiser *Gazelle*, which had also been fitted out with Niclausse boilers. At the first trials faults in construction of the pipes were discovered, similar to those which in their time led to the catastrophe on board the *Brandenberg*. A year and a

half ago, the *Gazelle* had to be put out of commission in order to make a thorough change in the boiler plant.—"Mit. Geb. Sew."

Fürst Bismarck.—Upon the outbreak of trouble in China last year, this armored cruiser, which had just completed her trials, was despatched from Kiel to join the German Asiatic Squadron. She left Kiel on the 30th of June, going through the Kaiser Wilhelm Canal and using only one engine for this part of the trip. She passed Dover at 4 A. M., July 2d, and from that time a speed of about 15 knots was maintained. The following particulars are from "Marine Rundschau."

Left.	Arrived.
Dover, June 30, 4 A. M.	Gibraltar, July 5, 6·15 P. M.
Gibraltar, July 6, 11·55 P. M.	Port Said, July 12, 5·00 P. M.
Suez, July 14, 9·30 P. M.	Aden, July 18, 1·55 P. M.
Perine Island, July 20, 3·45 P. M	Colombo, July 26, 10 P. M.
Colombo, July 27, 10·45 P. M.	Singapore, August 1, 3·30 P. M.

At Aden some difficulty was experienced in getting coal at the outer anchorage, so the ship went back to Perine Island.

The following tabular statement is a record of the time in port and of the actual time of coaling and the quantity taken:

Port.	In port.	Coaling.	Coal.	Tons per hour.
	H. *M.*	*H.* *M.*	*Tons.*	
Gibraltar	29 40	23 15	960	41.3
Port Said	6 20	4 35	381	83.1
Suez	28 30	22 15	844	37.9
Perim Island	19 15	14 50	838	56.5
Colombo	24 45	12 20	1,050	85.1

The coal at Colombo was in bags and was brought off in 25-ton lighters. In none of the ports were the bunkers completely filled, on account of the difficulty of stowage.

The total distance, neglecting the Suez Canal, is given as 8,352 miles, and the average speed 14.6 knots. The speed through the Red Sea was 15 knots, the ship using her three engines.

Hagen.—The lengthening of this vessel, one of the *Siegfried* class of coast-defense vessels has been completed, and she is about completing her trials. The vessels of this class, have proved unsatisfactory in many ways, lacking in stability, speed

and endurance, but the alterations in the *Hagen* have resulted so successfully that similar changes are contemplated in the others.

The *Hagen* was cut in two amidships, and lengthened a distance of seven frame spaces (8.4 meters). While this work was in progress other important changes were made, the principal ones being the substitution of Thornycroft for locomotive boilers, the addition of two 3.46-inch rapid-fire guns, the removal of the foremast, which was simply a signal mast, and the substitution of a military mast with 37-millimeter machine guns in the top, and the addition of a flying bridge between the forward and after bridges. The armor on the conning tower was materially increased in thickness, and the new boilers fitted for burning oil in conjunction with coal. The new boilers require two smoke pipes instead of one, so that the appearance of the ship has been materially changed.

Below are given the principal data before and after alteration:

	Before.	After.
Length between perpendiculars, feet	239.5	267
Breadth, extreme, feet	48.97	49.07
Draught, mean, feet	17.46	17.46
Displacement, normal tons	3,500	4,114
Battery, 24-cm. 35-caliber, number	3	3
8.8-cm. R. F., 30-caliber, number	8	10
37-mm. machine guns, number	None.	6
8-mm. machine guns, number	6	4
Torpedo tubes, 35-cm., bow, submerged, number	1	1
broadside, above water, number	2	2
stern, above water, number	1	1*
Conning tower, thickness, inches	3.15	7.08
Coal bunker capacity, tons	220	580
Coal bunker, normal, tons	220	350
Fuel-oil space, tons	None.	1.7
I.H.P.	4,483	5,178
Speed, knots	14.85	15+
Turning circle at 12 knots, yards	400	430

*Armored.

The *Hagen* has a complete armor belt, which is 9.45 inches thick amidships and tapers to 5.9 inches at the bow and 7.1 at the stern, these latter figures being the thickness above water, from which it tapers to 3.9 inches at the bottom. Her protect-

ive deck is 1.18 inches thick.—Translated from "Marine Rundschau," January, 1901.

Medusa.—"Ueberall," the organ of the German Navy League, states that the small German cruiser *Medusa*, which was launched at the Weser Yards, Bremen, on Wednesday, December 5th, and hitherto known as *E*, is the seventh ship of the *Gazelle* type. She differs, however, from the *Gazelle* and *Niobe* in having no wood or copper in her construction, resembling in this respect the *Chetis*, *Ariadne*, *Amazone* and *Nymphe*. Her length is 344½ feet; beam, 38¾ feet; draught, 16 feet; displacement, 2,650 tons; engines, 8,000 horsepower; speed, 20 knots, or ten knots for 5,000 miles, with a coal supply of 500 tons; armament, ten 4.13-inch guns, eighteen machine guns, and two submerged torpedo tubes; her only protection is an armor deck of 1.97-inch maximum thickness; her complement is 249 officers and men.—"Engineering News."

Niobe.—The trials of this cruiser were completed during July and August of last year. Her keel was laid at the Weser Works, Bremen, on the 30th of August, 1898, and she was launched July 18, 1899.

The principal particulars of the design are: Length between perpendiculars, 360.9 feet; breadth, extreme, 38.71 feet; draught —forward, 15.09 feet; aft, 16.31 feet; mean, 15.70 feet; displacement, 2,600 tons; I.H.P., 7,890.

The has two vertical, triple-expansion engines, each with four cylinders, 30.7, 44.5 and 51.2 inches diameter, there being, of course, two of the latter. The stroke is 28.35 inches, and the designed revolutions at full power, 170. The valve gear is of the single eccentric type.

Steam is furnished by eight Thornycroft boilers in two compartments working under a pressure of 213 pounds. The grate and heating surfaces are, respectively, 420 and 21,740 square feet.

The screws are three-blade and of manganese bronze; they are 11.48 feet diameter and of expanding pitch, the mean being 15.09 feet, but for the trials it was set at 16.4.

The preliminary trials for the purpose of drilling the engineer's force were run from the 10th to the 12th of July, and were at dif-

ferent speeds, finally working up to full power. These were succeeded by the following trials, in order: A six-hour forced-draft trial; two coal-consumption trials, each of 24 hours duration, with three boilers in use; another similar trial with all boilers in use, and a 72-hours endurance trial. The particulars of these trials are:

Duration, hours	6	24	24	24	72
Draught, mean	15.66	15.73	15.68	15.81	15.81
I.H.P., main engines	8,000	913	1,204	3,586	4,852
Air pressure, inches	1.3	(*a*)	(*a*)	(*b*)	0.4
Revolutions	166.6	79.6	87.25	127.25	140.3
Speed, knots	21.6	...	...	...	19.45
Coal, per square foot grate	(*c*)	17.0	19	17.4	25.1
Coal, per I.H.P	(*c*)	2.41	2.13	1.86	2.01

(*a*) Natural draft; (*b*) Blowers running; (*c*) Not measured.

The ship had measured-mile trials on the 9th of August, the details of which are given below. The mean draught was 15.75 feet.

Speed.	I.H.P.	Revolutions per minute.
21,594	8,511	166.4
17,048	3,505	126.73
11,979	1,183	87.09
11,189	945	81.03

The battery of the *Niobe* comprises ten 4.1-inch R.F., fourteen 37-millimeter, and four smaller guns. She mounts two torpedo tubes, one of which is submerged.—" Marine Rundschau."

Nymphe.—The new small cruiser *Nymphe* (described on p. 256, Vol. XII, of JOURNAL) has been carrying out her trials off Kiel. With the engines making 158 revolutions, and developing a little over 9,000 I.H.P., a speed of 22.3 knots was attained, showing a vast improvement over the *Gazelle*, the first ship of the class, whose maximum speed is only 19 knots. The *Nymphe* is fitted with Schultz water-tube boilers, and the estimated speed was to be 21.5 knots.—"Journal R. U. S. I."

Victoria Louise.—The new second-class cruiser *Victoria Louise* has been undergoing her trials successfully. With the engines developing 10,000 I.H.P. she maintained a mean speed

of 18.5 knots. She is fitted with water-tube boilers of the Dürr type.—"Journal R. U. S. I."

(For data of previous trials see p. 1110, Vol, XI, of JOURNAL.)

ITALY.

Garibaldi.—The Italian armored cruiser *Garibaldi* has had her trials at Genoa after the late change in her boilers. During the trial all twenty-four boilers were used, 14,200 I.H.P. were obtained at full power with 108 revolutions and a speed of 19.7 miles. The efficiency of the machinery was therefore increased by 700 I.H.P.—"Mit. Geb. Seew."

Reina Elena and Vittorio Emmanuele III.—At Spezia and at Castellamare the ways are being prepared for the laying down of the battleships on the plans of Inspector Masdea and Inspector Cuniberti. These battleships will be named *Reina Elena* and *Vittorio Emmanuele III.* The *Elena* will be 476 feet long, 433 feet between perpendiculars, and 75 feet beam, with a displacement of 12,600 tons. Her armament will include three 12-inch guns (305 millimeters), twelve 8-inch guns (293 millimeters), twelve 12-pounders, twelve of less caliber, and four torpedo tubes. The belt will be 8.2 inches thick at the water line. Coal capacity, 2,000 tons. Engines will be 20,000 I.H.P.; speed, 22 knots; radius of action, 10,000 miles.

The *Vittorio Emmanuele III* will have a length of 475 feet; between perpendiculars, 431 feet; beam, 73 feet; draught, 26 feet; displacement, 12,624 tons. The armor belt will be 8 2 inches thick, and the armored deck, 1.6 inches thick. The armament will be the same as that of the *Elena*, except that there will be but two guns of 12 inches. Engine power the same as the *Elena.*

Varese.—The steam trials of this armored cruiser, a sister to the *Garibaldi*, have been concluded with satisfactory results. She was built by Orlando Brothers, Leghorn, and is of the following dimensions: Length, 344 feet; beam, 61.25 feet; draught, 23.25 feet; displacement, 7,590 tons.

The propelling machinery consists of twin-screw, vertical, triple-expansion engines, each in a separate water-tight compart-

ment, and of twenty-four Belleville boilers in two groups of twelve each, one forward and the other aft of the engines. The boilers of the forward group are arranged in two compartments, of which the forward one contains four boilers, in pairs, placed against the after transverse bulkhead, with the fire room forward; the second compartment contains eight boilers similarly arranged in pairs, with two fire rooms, one forward and the other aft. The boilers of the after group are similarly arranged. There are two smoke pipes.

Each engine has three cylinders, 41, 63 and 93 inches diameter, the H.P. forward and the L.P. aft. The stroke is 46 inches. Piston valves are used on the high-pressure cylinder and slide valves on the intermediate and low-pressure. The cranks are at angles of 120 degrees.

The total grate surface of the boilers is 1,047.5 square feet, and the heating surface, 33,910, of which 21,942 square feet are in the tubes and 11,968 square feet in the economizers. Of the forward boilers, two are composed of six elements, six of seven elements, and the remaining four of eight elements. Of the after ones, six have six elements and six have seven elements. All elements have seven rows of tubes, each 7 feet 6½ inches long and 4.57 inches diameter. The thickness of the two rows of tubes next the furnace is .275 inch and of the remaining ones .169 inch.

Of the forward economizers, eight have five elements, and four six elements each; the after ones have five elements each. These elements are all composed of twelve rows of tubes 6 feet 4¾ inches long, 2¾ inches outside diameter and .126 inch thick.

The smoke pipes are 6 feet 6 inches diameter and 72 feet in height above the grates.

The screw propellers are three-bladed, 16 feet 9 inches diameter and 23 feet 4 inches pitch.

The contract requirement was that 13,500 I.H.P. should be obtained, with a pressure of 213 pounds in the boilers, reduced to 155 pounds at the engines, the revolutions of the engines not to exceed 116 per minute.

The natural-draft trial took place October 20th, last, the vessel

having come out of dock two days previously. The full-power trial was run November 27th. The following are the data of these trials:

	Natural draft.	Forced draft.
Mean draught, feet	23.18	23.25
Displacement	7,470	7,475
Duration of trial, hours	6	1½
Steam pressure in boilers, pounds	155	201
Steam pressure at engines, pounds	132	154
Coal per square foot grate, pounds	17.87	24.98
Air pressure, inches		.6 to .85
Revolutions per minute	95.71	105.6
I.H.P.	9,348	13,650
Speed, knots	18,352	20.02
Slip, per cent	16.84	17.8

During the natural-draft trial, all boilers were in use, the fans were in operation and the fire rooms open. During the forced-draft trial, the jackets were not in use.—From "Rivista Marittima."

JAPAN.

Hatsuse.—The Japanese battleship *Hatsuse*, built by Sir W. G. Armstrong, Whitworth and Company, Limited, from designs by Mr. P. Watts, and engined by Messrs. Humphrys, Tennant and Company, has now completed her official trials at the mouth of the Tyne.

The vessel has a displacement of 15,000 tons; her length is 400 feet, her breadth is 76 feet, and her draught of water is 27 feet. Her armament consists of four 12-inch guns, in pairs in barbettes on the middle line at the extremities of the ship, fourteen 6-inch guns in casemates—six on the upper deck and eight on the main deck; twenty 12-pounders, twelve 3-pounders, a number of smaller guns, and four 18-inch underwater torpedo tubes. The armor consists of a complete belt from stem to stern, 9 inches thick over the central portions, including the machinery and magazines, and tapered to 4 inches at the extremities. Over the central portion the armor rises to the main deck, forming a citadel, protecting the bases of the main deck casemate guns. This armor is 6 inches thick on the sides and

12 inches over the bulkheads. The barbettes protecting the 12-inch guns are of 14-inch armor, and the casemates protecting the 6-inch guns are of 6-inch armor. All of the armor is the tough, hard-faced armor recently introduced.

A trial of six hours duration with four-fifths of full power was made on December 5th, *en route* from Chatham (where the ship had been docked), when a speed of 18 knots, based on revolutions, was maintained. The vessel reached the mouth of the Tyne early on the 6th, when she was joined by the firing party. Ammunition for the gunnery trials was at once taken on board, and these trials were satisfactorily carried out during the day, and demonstrated that the hull of the vessel was well able to stand the stresses to which it was subjected. The next day, the vessel having been brought to the required draught by the admission of water to the double bottom, the full-speed trials were proceeded with. The vessel ran for upwards of three hours at a speed exceeding 19 knots by revolutions, the mean of four runs over the measured mile giving a mean speed of 19.1 knots. The mean power developed over the three hours exceeded 15,000 I.H.P. Turning, starting, anchor and other trials have since been made, and the vessel has now returned to her moorings off Jarrow Slake, where the final opening up of the machinery and painting is being rapidly pressed on with, and it is expected that the vessel will sail for Japan in a few weeks.

It is interesting to note that throughout the whole of the steam trials, which extended over several days, the stoking was performed by the Japanese stokers belonging to the ship.—"Engineering."

RUSSIA.

Askold.—The second-class cruiser *Askold* (described on page 575 of Vol. XII, of the JOURNAL), which will shortly be taken over by the Russian naval authorities, is described as a commerce destroyer of medium displacement, and a splendid specimen of that class. She is to attain a speed of not less than 23 knots, the engines to develop an I.H.P. of 19,000, with a displacement of about 5,900 tons. The Shipbuilding and Mechanical Engineering Society at Kiel is to pay a fine of 20,000 roubles (£3,200) for

every quarter of a knot short of the contract speed, if less than 21 knots is made; but above 20, the vessel may be accepted subject to a penalty in addition of 80,000 marks (about $20,000). The expenditure of coal per I.H.P. per hour is not to exceed 2 pounds. The stability is to be tested by the firing of the guns at various angles. The cost of the hull and engines, the boilers being of the Thornkraft-Schultz pattern, is about 3,075,000 roubles (about $2,450,000). The order was given to the Germania Yard early in August, 1898.—"Journal, R. U. S. I."

Astrabad.—The Sormoro Company, on the Volga, is now nearly ready with a steel twin-screw cruiser called the *Astrabad*, destined for service on the Caspian at Ashur-Ade. Her displacement is 430 tons, and her main dimensions are as follows: Length, 125 feet at water line; beam, 22 feet; depth of hold, 12 feet 6 inches; mean draught at full load, 7 feet 6 inches. She will be launched (or floated) next spring. She has two cylindrical, double-ended boilers and two compound engines of 500 I.H.P., giving her a speed of 12 knots. Her armament will consist of four 6-pounders and four 3-pounder Q. F. guns. She has a ram strengthened with transverse bars for ramming purposes.—"Journal, R. U. S. I."

Bohatyr.—The protected first-class cruiser *Bohatyr*, under construction at the Vulcan Yard, at Stettin, belongs to the same type as the *Askold* and *Variag*, though with different armor. Her displacement is 6,500 tons, and her principal dimensions are: Length at the load-water line, 428 feet 9 inches; extreme beam, 54 feet 1 inch; draught, 20 feet. The armament consists of twelve 6-inch Q. F., as many 3-inch Q. F., and six Hotchkiss guns, these being protected by armor of nickel-steel, varying from 3 inches to 5 inches. There will be six torpedo-ejecting tubes, two being under water. The armored deck varies from $1\frac{1}{2}$ to $2\frac{3}{4}$ inches. The twin screws are worked by two triple-expansion engines with four cylinders; the boilers are on the Normand system. The estimated H.P. should not be less than 19,500, giving a speed of 23 knots, engines and boilers being produced at the works. The ordinary coal supply is 750 tons,

though the bunkers can hold 1,100 tons. Her complement, including officers, will be 580 men.—"Journal R. U. S. I."

Gromoboi.—The first-class armored cruiser *Gromoboi* (described in Vol. XI, p. 803, of the JOURNAL) was recently tried, by the committee for taking over ships, on the measured mile, the engines being put at full pressure for six hours uninterruptedly, and five series of diagrams taken, the result slightly exceeding the I.H.P. contracted for, viz: 14,500. All three engines left nothing to be desired in construction and putting together, a new departure of the Baltic Works, but, unfortunately, some quarter of an hour before the end of the trial the valve rod of the mean-pressure cylinder of the starboard engine broke, and the trial had to be stopped. The trial was carried out at a normal draft and the mean speed of the cruiser by the bearings was determined at 20 knots.—"Journal R. U. S. I."

Training Ship for Firemen and Stokers of Russian Baltic Fleet.—Soon there will be commenced at one of the St. Petersburg docks the building of a training vessel for the engineers and stokers of the Baltic Fleet. The plans are now in readiness, and the hull is to be built of Siemens-Martin steel, at a cost of 3,000,000 roubles (about $2,400,000). The existence of such a vessel is necessitated by the rapidly increasing staff of such officers, which makes it necessary that those training for it should be brought together on board a vessel specially fitted for the work. All the necessary apparatus will be provided for enabling the aspirants to learn the work, and the building of the vessel is a great proof of the improved condition of technical education, and there is no doubt that the money will be well spent. All sorts of experiments and trials will be able to be carried out on board, which will give a specially learned coloring to the instruction there given.—"Journal of Royal United Service Institution."

Osiotr, Kefal and Losos.—With regard to the three large torpedo vessels, *Osiotr*, *Kefal* and *Losos*, under construction at the Forges et Chantiers de la Méditerranée, every endeavor is being used to combine great lightness with as much strength as possible, the method of securing the hulls, decks and compart-

ments, and the quality of the material, contributing largely to this result. All the outer sheeting and angle steel are made of a special nickel-steel with high resistance to explosives, the proportion of nickel being 4 per cent. In spite of the difficulty of working with this material, the work has been done with great neatness. The sheathing is zincked under water and to a certain height above the water line. Each of them carries five 47-millimeter Q. F. guns and one 75-millimeter gun with a shield, and they have two ejecting torpedo tubes. They are to have two vertical, triple-expansion engines, which are to be tested to a pressure of 22 kilogrammes to the square centimeter, and at full speed of 26 knots should develop a H.P. of 4,750 for the two engines at 310 revolutions a minute. There are to be four water-tube boilers of the Normand pattern to each. The pipes of the boilers are of the softest steel, without joint. The hull under the boilers and engines has been strengthened with riders and specially strong timbers and keelsons. They are to be subjected first to an eight hours' trial at 14 knots, with regard to the expenditure of fuel, and then as to the utmost speed they can attain for six hours, and then as to the behavior of the engines under a speed of 22 knots, and within two hours once again at full speed. The quantity of coal taken for the trip will be estimated for 950 miles at a speed of 14 knots, or 1,860 at 10 knots. Should they attain a speed of less than 26, but more than 24 knots, they may be accepted, but subject to a fine of 15,000 francs (£600) for every quarter of the first knot, and 25,000 francs (£1,000) for every quarter of the second knot. The torpedo gear, guns, carriages, etc., will be sent from Russia. The total cost of each, including transfer and trial, will be about 1,500,000 francs (£60,000).—"Journal R. U. S. I."

Peresviet.—The official trials of the engines of the first-class armored cruiser *Peresviet* (described in JOURNAL, Vol. X, p. 894, and preliminary trials, Vol. XII, p. 260), held under the auspices of the committee presided over by Rear Admiral Diker, at full pressure on a six hours' trip, showed a mean speed by bearings of 19.12 knots.

The I.H.P. was, on an average of five sets of cards, as follows:

Port engine, H.P. cylinder, 1,292.10; I.P. cylinder, 1,616.48; L.P. cylinder, 1,728.84; total for port engine, 4,637.42 I.H.P. Starboard engine, 4,445.11 I.H.P.; mean number of revolutions, 101.6, with 143.7 pounds of steam. Amidships engine, 4,692.84 I.H.P. The total I.H.P. for all three engines worked out at 13,775.37, or 725 H.P. less than required by the specification. This is accounted for by the irregular working of the boilers, but the engines, on the whole, worked well, which they did not do last year, there being a heating of the bearings. The average number of revolutions was 102 with 139 pounds pressure in the engine and 165 in the boilers.

Retvizan.*—The following are the dimensions of the first-class battleship *Retvizan*, which was launched from Cramp's Yard at Philadelphia on the 23d of October last: Length between perpendiculars, 374 feet 1 inch; beam, 72 feet 2 inches; extreme draught, 27 feet 3 inches; approximate displacement, 12,700 tons.

Protection is afforded by an armor belt with a maximum thickness amidships of 9 inches, tapering forward to 4 inches, and extending from the ram to just abaft the after barbette, or about two-thirds the length of the ship; there is an armored turtle-back deck, 2 inches thick in the horizontal part and 4 inches on the slopes, which begins on a level with the upper edge of the belt and ends at the lower, as in the ships of the *Majestic* type; the belt has a depth of 7 feet 6 inches. There is a further coal protection of 10 feet, corresponding to 4 inches of steel, so the engines are well protected. Above the belt is a central casemate protected by 6-inch armor, while on the barbettes, one forward and one aft, the armor is 10 inches thick; the casemate is shut in fore and aft by athwartship bulkheads of 9-inch steel. All the armor is Krupp steel hardened by that firm's latest process. The armament consists of four 12-inch 40-caliber guns in the barbettes, with an arc of training of 340 degrees, the turrets being worked by either electricity or hand; twelve 6-inch Q.F. 45-caliber guns, of which eight are mounted in the central battery, separated by 2-inch bulkheads, and with

* For additional particulars see JOURNAL, Vol. XII, p. 1,114.

a training arc of 120 degrees, and four in the superstructure above the redoubt, with a training arc of 180 degrees, and protected by cylindrical shields; eight 3-inch Q.F. guns, four before and four abaft the central redoubt, and six more between the 6-inch guns on the superstructure, and two mounted on the deck above, one on each beam; twenty-four 3-pounder and six 1-pounder Q.F. guns distributed in different parts of the ship, six torpedo tubes, one forward, one aft, and two on each beam. The normal coal supply will be 1,000 tons, but arrangements will be made for carrying 2,000 tons, which will give a radius of action of 8,350 miles at 10 knots and 3,000 miles at 18 knots. The engines will be triple-expansion, with twenty-four Niclausse water-tube boilers, which are to develop 16,000 I.H.P., giving 126 revolutions, and an estimated speed of 18 knots. She will have a complement of 750 officers and men.

A trial was lately held at the butts at Carnegie Works of the armor plates intended for the battleship *Retvisan*, under construction at the Cramp Works, these being 6 inches in thickness, 9 feet high, and 8½ feet broad. Five shots were fired with A.P. projectiles from 6-inch guns, the mean velocity being 1,905 feet per second. The third shot gave an energy of 2,553 foot-tons, but only penetrated 3½ inches. In the other cases the projectiles broke up, only producing unimportant erosions on the surface of the plate, which was nowhere cracked. At the fifth shot the projectile broke to pieces, and only starred the plate all over, making indentations in no case more than 1⅛ inches. The armor is for the casemates of the battleship.—"Journal, R. U. S. I."

Sevastopol.—The official trials of this battleship gave the following results: Steam pressure at engines, 142 pounds; revolutions, port, 84; starboard, 88; I.H.P., port, 4,630.7; starboard, 4,736.8; total, 9,367.5. The designed I.H.P. is 10,600.

Tsarevitch.—The particulars of the Russian battleship *Tsarevitch* soon to be launched at Toulon are as follows: length, 388 feet 9 inches; beam, 76 feet 1 inch; draught, 26 feet; displacement, 13,000 tons; I.H.P., 16,300; speed, 18 knots.

The armament will be as follows: four 12-inch and twelve 6-

inch guns in turrets; twenty 3-inch guns, sixteen in batteries and four on the bridges; twenty 1.85-inch guns, twelve on the bridges and eight in the tops; two Baranovsky guns for landing; four Maxims; four 1.85-inch, and two 1.45-inch guns for the launches; four torpedo tubes, two submerged, and two above water. She will also carry two torpedo boats 56 feet in length. —"The Engineer."

MERCHANT STEAMERS.

Atlantic Transport Co.'s New Steamers.—The largest ship-building contract for merchant craft that has ever been awarded to a ship-building firm on the Delaware river at one time has just been awarded to the New York Ship Building Company, Camden, N. J., by President Baker, of the Atlantic Transport Company, which has hitherto owned only foreign-built ships. It should be understood, however, that the company latterly gave a contract to the Maryland Steel Company for two steamships. The four vessels are intended for the transatlantic service and will ply between London and Philadelphia, Baltimore and New York. Two of the ships are to be 600 feet long and the others a few feet shorter. Their equipment will be equal to anything engaged in the Atlantic service. The two largest vsssels are to be of 12,000 tons capacity, and the four when completed will cost the company over $5,000,000. Each vessel is to be constructed of steel throughout and will be built in excess of the underwriters' requirements. The machinery will consist of triple-expansion engines, and boilers of the Scotch type, able to withstand the highest pressure for vessels of that type. This award, given to the New York Ship Building Company, makes eight steamships to be constructed by that concern, the others being three vessels for the American-Hawaiian Steamship Company and a passenger steamer for Robert Dollar, of San Francisco, to be engaged in the Yukon river trade.—"Marine Review."

More Orders for Big Ships.—The American Ship Building Co. has just concluded arrangements with eastern capitalists represented by Charles E. & W. F. Peck, of New York, for the construction of two steamers to engage in transatlantic service and to carry 7,000 gross tons cargo with about 1,000 tons fuel capacity on 25½ feet draught at 10 knots speed. This is the first move on the part of the big lake ship building organization to

build in two parts ships of large capacity for salt water service. These vessels will each be towed through the St. Lawrence canals in two parts and put together at Montreal or some other point below the shallow waters of the St. Lawrence. Dimensions are to be 430 feet keel, 450 feet over all, 43 feet beam and 35 feet depth. A 5-foot water bottom will be provided and the ships will be of the three-deck type. They will each have four Scotch boilers, fitted with Howden draft, and triple-expansion engines capable of developing about 3,000 H.P. They will be finished before the close of navigation next fall, and will cost about $450,000 each.

A very important order for new vessels has been closed by General Manager James Wallace of the American Ship Building Co., bringing the number of steel ships under way in the different works of that company up to thirty. This latest order is from Mr. Frank H. Peavey of the Peavey grain elevator interests of Duluth, and is for four steel freight steamers, to cost nearly $1,500,000. The vessels will be duplicates and similar in nearly all respects to the Minnesota line steamer *Mataafa*, which was originally owned by Mr. A. B. Wolvin of Duluth and first named *Pennsylvania*. Dimensions of the new vessels will be 450 feet over all, 430 feet keel, 50 feet beam and 28½ feet deep. They will have quadruple-expansion engines and steam will be furnished by Babcock & Wilcox water-tube boilers. Two of them will come out next September and the other two will be ready for sea the following month.—"Marine Review."

Alaskan and Arizonian.—These fine vessels are building at the Union Iron Works, San Franciso, for the American-Hawaiian Steamship Co., and, being alike, a description of one will be a description of both. The *Alaskan* is a steel twin-screw steamer, built to Lloyd's three deck rule, having a complete shelter deck, Her length between perpendiculars is 471 feet 1 inch; beam, molded, 57 feet; depth, molded, to shelter deck, 42 feet 6 inches. A generous height is allowed between decks, to facilitate the stowage and handling of cargo. The *Alaskan* is built on the deep-frame principle. This vessel when loaded to a depth of 27 feet is to carry 11,000 tons, including water in boil-

ers, and will rank 100 A1 at Lloyd's. The rig will consist of two short, straight masts used for handling cargo and steadying sails only. Along each side of the vessel will be fitted three short steel posts carrying cargo hoists to work intermediate hatches not reached by the booms on the two main masts. In connection with the cargo-handling gear fifteen vertical steam winches will be installed, special care having been taken with the leads to booms and such matters, so that the most expeditious handling of cargo may be insured.

The motive power of this vessel consists of two sets of four-cylinder quadruple-expansion engines, supplied with steam from three Scotch boilers fitted with the Howden hot-air forced draft, the fans for this system being driven by two Union Iron Works compound, single-valve engines. The engines when working at full power are designed to develop 3,000 H.P. and give a speed loaded of from 10 to 10½ knots. The high and first intermediate-pressure cylinders are entirely separate and free from the low and second-intermediate cylinders, thus allowing for expansion between the cylinders. The designed working pressure of the boilers is 212 pounds. The shafting throughout is of Bethlehem fluid-compressed steel, the crank shafts being in four sections and interchangeable, placed 90 degrees apart. Between the thrust shafts in the after end of the engine room the electric generating plant is to be situated, which will consist of two dynamos of ample capacity for the lighting and electric power of the ship, driven by two automatic compound electric-light engines; the main engines to be fitted with the usual two-cylinder turning engines for use in port. The circulating pump to be of ample capacity to condense the steam from the main engines, and will be driven by compound engines. The usual outfit of ballast, fire and sanitary pumps will be carried. Located in the engine room will be a large electrically-driven ventilating fan, with ducts leading to the different holds throughout the vessel for insuring a supply of fresh air under all conditions to the different holds.

Cowrie.—The steamship *Cowrie* lately made the voyage from Koetei, Borneo, to London, 9,250 miles, using only liquid fuel. She employed only six stokers instead of sixteen with coal.

The oil consumption was 22 tons per day, against 35 tons of coal, and as a ton of oil occupies 35 cubic feet, while a ton of coal demands 45 cubic feet, the saving in bunker space was considerable. In loading, the oil was put aboard at the rate of 300 tons per hour. Oil at Borneo is $7.50 per ton.

S. S. Esperanza.—The *Esperanza* is the fourth steel steamship built by the Cramps for the New York and Cuba Mail Steamship Company within two years. The hull dimensions of the vessel are 341 feet in length, 47 feet 6 inches beam, depth of hold, 36 feet, and she will draw about 20 feet of water loaded. She has a double bottom with a center-line keelson that will be watertight to the extent of the engine and boiler space, thus forming a watertight compartment for both boilers and engines on either side.

This vessel will have two three-cylinder, triple-expansion, surface-condensing engines of the vertical marine type, which will make 4,500 indicated horsepower at ninety-seven revolutions, with a working pressure of 160 pounds. The diameter of the cylinders will be as follows: high pressure, 23½ inches; intermediate, 39 inches, and low pressure, 65 inches, all with a common stroke of 42 inches. She will have four single-ended boilers of the return-tube, cylindrical type, with 15 feet 2 inches outside diameter, by 10 feet 5 inches long. The twin propellers will be of manganese-bronze of three blades each. She will also have a complete outfit of Blake air pumps, including vertical twin air pumps, U. S. Navy pattern.

No wood excepting where absolutely necessary will be used in the construction of this ship. The deck houses will be of steel throughout. The pantries, bathrooms and galleys will be tiled, and the passageways will be tiled in interlocking rubber tiling.

A 16-knot rate of speed is guaranteed by the builders for continuous service, and 17 knots on the trial trip. There will be accommodations for 75 first-cabin passengers, 40 second and 75 in the steerage.

Grecian.—This vessel was built not long since at the yard of

Harlan & Hollingsworth, Wilmington, Del., for the Boston and Philadelphia S. S. Co.

The *Grecian* is a steel vessel, built to carry about 2,500 tons deadweight, and about 100 passengers, at the rate of 15½ knots, in the coast trade between the ports of Philadelphia and Boston.

Her dimensions are: Length between perpendiculars, 263 feet; length over all, 290 feet; beam, molded, 42 feet; depth at center to hurricane deck, 36 feet; gross tonnage, 2,483 tons.

The *Grecian* is a single-screw vessel, the propelling engine being of the usual vertical, triple-expansion type with cylinders 25 inches, 41½ inches and 68 inches diameter and 42-inch stroke. They were designed to turn up about 90 revolutions with 170 pounds boiler steam pressure. The I.H.P. is 2,650. The front columns are forged and the back are of cast iron surmounting the condenser. For the H.P. and I.P. cylinders piston valves are used, and for the L.P. a slide valve, all being worked by the Stephenson link motion. Steel is the material used for the crank shaft, and this is 12¾ inches diameter, in two sections. The pins measure 12¾ inches diameter by 13 inches long. Both air and bilge pumps are worked direct off the main engine, the former having a barrel 24 inches diameter and 21-inch stroke. Cast iron is used for the propeller, which is of the built-up type, 15 feet diameter.

Hawaiian.—The big freighter *Hawaiian* of the American-Hawaiian Steamship Company was launched at Roach's ship yard, Chester, Pa., on November 7. Mrs. W. C. Sproul, wife of the State Senator from Delaware county, christened the vessel. The new boat is one of a fleet of seven steamers. Her dimensions are: Length, 435 feet; beam, 51 feet; depth, 33 feet to water bottom. Her gross tonnage will be 6,000, and she is fitted with triple-expansion engines of 2,500 H.P., and will carry 8,250 tons of freight.

Pere Marquette.—Probably the most remarkable car-ferry steamer on this continent, if not in the world, is the *Pere Marquette*, which is operated between Ludington, Mich., and Manitowoc, Wis., and which has succeeded in keeping navigation open on her fifty-six-mile route across Lake Michigan during

the severest winters of the past decade. This vessel is 350 feet in length, 56 feet in breadth and 36 feet deep. She displaces over 4,000 tons on a draught of twelve feet, and her usual cargo consists of thirty loaded freight cars. When the *Pere Marquette* went into drydock for repairs in the autumn of 1899, she had traveled more than 40,000 miles without any attention from the refitters, and when it is explained that much of this service had been at a speed of ten miles per hour through ice fourteen inches thick, some idea of the wonderful staunchness of the vessel may be gained.

It will doubtless surprise many readers to learn that officers of the Flint & Pere Marquette Railroad Company, which operates the vessel just described, are unanimous in the declaration that she does more satisfactory work in the intensely cold weather than when a milder temperature prevails. Very frequently in the dead of winter, when the thermometer ranges from eighteen to thirty-five degrees below zero, the ice in the path of the *Pere Marquette* varies from hard blue ice of a foot thickness to fifteen feet of snow-ice where it has windrowed; and yet the vessel has never consumed more than forty-eight hours in making any one trip.

All of these car ferries are provided with the necessary jack-screws, chain, clamps, etc., for firmly securing the railroad cars; and the loading and unloading docks are equipped with a novel device corresponding to a giant gang-plank, which adjusts itself to the movement of the waves and thus enables cars to be transferred even though a heavy sea be running. There have been occasions in rough weather when cars have been loosened from their fastenings while in transit, and have collided with other cars, inflicting considerable damage; but, of course, these instances are rare.

Occasionally, too, the smaller and less powerful car ferries, such as those in service across Lake Erie from the American to the Canadian shore, become imprisoned in floating fields of ice, and a year or two ago the ferry steamer *Shenango* was thus imprisoned for nearly a month.—"Scientific American."

Sabine.—The hydraulic dredge *Sabine* was launched on November 24 by the Townsend & Downey Shipbuilding and Repair Company, at their new yard at Shooter's Island, off Staten Island, N. Y. This dredge is 150 feet long, is built to go to sea under her own steam, and is to have a speed of 10 to 12 knots from her twin screws. She is to be put to work on the Sabine Canal, on the Texan coast and is arranged to carry the dredged material in her own hull.

Samson.—The twin-screw dredger *Samson*, which has been bullt by Messrs. Sir W. G. Armstrong, Whitworth and Co., Ltd., at their Walker Shipbuilding Yard for the Queensland Government and which, along with a smilar class of vessel, *Hercules*, is to be employed at first on important improvements of the harbor at Brisbane, had its speed-trial trip on 9th of December, which proved in every way most satisfactory. The *Samson* is the fourth and largest vessel of the type that has been completed during the year just closed by Messrs. Sir W. G. Armstrong, Whitworth and Co., Ltd., to the order of Mr. Lindon W. Bates.

As already indicated the *Samson* is larger than the *Hercules*, being 10 feet longer, 12 feet broader and 2 feet deeper, the actual dimensions being: length over all, 245 feet 6 inches, length between perpendiculars, 220 feet; breadth, molded, 51 feet, and depth, molded, 15 feet. The hull is very substantially built, and has a double bottom. Joggling has been adopted in the shell plating on the Bell and Rockcliffe system. At the forward end of the vessel there are two dredging suctions with the requisite lowering ladders, the raising and lowering being effected by means of wire ropes worked from a powerful steam winch of special design, each of these suctions being provided with hollow milling cutters, formed of blades which are interchangeable and reversible, so that if exceptional wear takes place at one part of the blade, it can be withdrawn and replaced so as to secure greater longevity for the cutter. In case of the cutters being temporarily choked by debris, a water service is provided, whereby they can be quickly cleansed. An operating house is provided forward of amidships on the shade deck, from which not only the lowering and raising of the ladders and forward suctions are controlled, but also the

driving of the milling cutters and the anchoring of the dredger when engaged in its actual work by means of spuds.

While the *Hercules* has only one centrifugal pump with a discharge pipe of 33 inches diameter, the *Samson* has two pumps of equal capability, thus being for dredging purposes twice as powerful as the *Hercules*. Each of these pumps is driven by an engine of the triple-expansion type having cylinders 18 inches, 30 inches, 50 inches diameter, 30 inches stroke, the initial pressure of steam being 190 pounds per square inch, and the full power about 1,800 I.H.P. at 160 revolutions per minute. The propelling engines are also triple expansion. There are two sets, each of which drive a four-bladed screw propeller 6 feet 3 inches diameter. These engines are 12½ inches, 26 inches and 36 inches diameter of cylinders, 27 inches stroke, and with 190 pounds pressure of steam attain 175 revolutions per minute, indicating 625 H.P. each. A piston valve is fitted to the high-pressure cylinders, and an ordinary double-ported slide valve to the low-pressure and single-ported valve to the intermediate-pressure cylinders. The engines, which operate the cutters fitted in connection with the two bow-ladder suctions are of compound type, although working with the same initial pressure as the pumping and propelling engines, viz.: 190 pounds per square inch. These engines are each 13½ inches and 27 inches diameter of cylinders, 15 inches stroke, and at a speed of 160 revolutions each exert 120 I.H.P. The exhaust steam from all the engines passes to an independent condenser made of steel plate, and the air and circulating pumps are also independent, the air pump being one of Blake and Knowles', and the circulating pump by Messrs. W. H. Allen and Co., Bedford. Worthington pumps are adopted for feeding the boilers, pumping out the bilges, and for the deck and other water services, a Weir's patent evaporator is fitted, one of Kirkaldy's compactum feed heaters, and one of Henry Watson and Sons' patent filters. A Pickering governor is fitted to the engines driving the centrifugal pump and to those actuating the milling cutters. Electric light is fitted throughout the vessel, the installation having been fitted by Messrs. Clarke, Chapman and Co., Ltd., Gateshead.

The boilers in this vessel are of the Babcock-Wilcox marine type, which type was also adopted in the three dredgers—*Lindon W. Bates*, *Archer* and *Hercules*. In the *Samson* there are six boilers. The total heating service is 20,820 square feet, and the collective grate area 516 square feet.

It is specially noteworthy that the boilers are arranged to be worked with forced draft, the air being supplied by four fans driven by direct-coupled rotary-valve engines, two of these fans being 30 inches in diameter, discharging 11,000 cubic feet, and two being 40 inches in diameter, discharging 26,000 cubic feet against a pressure of one inch water gage at 400 revolutions. Each of the small fans supply one boiler, and each of the larger fans supply two boilers, the air ducts being taken down the back of the boilers into the ashpit at the rear, the amount of air being controlled by means of dampers worked from the front.

Four of the six boilers are grouped together in the center of the stokehole with a separate funnel rising immediately over each pair, and the two remaining boilers are arranged singly in the center line of the dredger, one forward and one aft. The boilers are capable of supplying steam for 5,000 I.H.P., with Queensland coal. Each boiler is composed of a number of sections of tubes, which are all expanded at the ends into wrought headers, there being no screwed joints or cast iron used in any part of the boilers. The whole of the installation has been manufactured and erected in accordance with the requirements of Bureau Veritas.

On the 6th of December the dredger left Walker, and proceeded outside the Tyne to carry out the speed trial. Four runs were made on the measured-mile, during which the propelling engines were opened out to their full extent, when a mean speed of 10 knots per hour was obtained. The trial was in every way satisfactory, and on the following day the dredger left for Brisbane, Queensland.—"Engineers' Gazette."

Siberia and Korea.—The steamships *Siberia* and *Korea*, building at the Newport News S. B. & D. D. Co.'s works for the Pacific Mail Co., will soon be launched, and are intended for service between San Francisco and Hong Kong, with Honolulu,

Yokohama and Nagasaki as ports of call. They will be capable of making 18 knots in regular service, and will be in nearly all respects the equal of the best ships afloat. Following are the dimensions of the vessel: Length between perpendiculars, 550 feet; length over all, 572 feet 4 inches; beam, 63 feet; depth, 40 feet; draught, 27 feet; displacement, about 18,600 tons. Accommodations will be provided for 200 first-class passengers, 30 white steerage and 1,200 Chinese. Quarters for the latter are arranged so that the space may be utilized for other purposes if unoccupied by Chinese. The hulls will be constructed of steel with frames spaced 32 inches apart throughout. A double bottom extends from stem to stern and is carried up to the turn in the bilge. There are four decks extending the whole length of the vessels, known as the lower, main, upper and promenade decks. In addition to these are the orlop and boat decks.

The main engines consist of two four-cylinder, quadruple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments. The cylinders are of following dimensions: high-pressure, 35 inches; first intermediate-pressure, 50 inches; second intermediate-pressure, 70 inches, and low-pressure, 100 inches diameter, with a common stroke of 66 inches. The engines are designed to develop 18,000 I.H.P. while running at 86 revolutions per minute. The cylinders are arranged in the following order: high-pressure forward, low-pressure, second intermediate-pressure and first intermediate-pressure aft. The engine framing consists of cast-steel columns of I-section, secured to the cylinders and bed plates. The bed plates are also of cast steel. The valves are of the single-ported piston type and are of cast iron. The link motion is the Stephenson link type.

All the cylinders are steam jacketed. The piston rods are of forged steel, fitted with cast-iron crosshead slippers lined with Parsons' white bronze, which work in cast-iron crosshead guides. The connecting rods are of forged steel, 138 inches long between center of crank and center of crosshead pin. The pistons are of cast steel and are of the dished pattern. The eccentrics are of

cast iron, keyed to the crank shafts. The eccentric rods and valve stems are of forged steel, the former being secured to the eccentrics by composition straps. Each main engine will be fitted with a steam and hydraulic direct-acting reversing engine and a 7-inch by 5-inch turning engine. The thrust bearings will be two in number, of the ordinary horshoe type, with fourteen shoes to each bearing. The stern-tube bearings will be of the ordinary brass sleeve pattern, fitted with lignum vitae. The crank shafts will be forged steel in four interchangeable sections. The thrust, line and propeller shafts will also be forged steel. All shafts will be hollow. From the stern-tube stuffing box to the propeller hub the propeller shafts will have sleeves of composition for protection against the corrosive action of the sea water. The propellers will be of the three-bladed type, the hubs being cast steel and the blades bronze. There will be two main condensers, one for each main engine. Each main condenser will have an independent air pump and two circulating pumps, the circulating pumps to be operated by a compound engine. Two auxiliary condensers will also be provided with combined air and circulating pumps attached. Two feed-water heaters will also be installed.

The boilers are to be nine in number, eight main boilers and one donkey boiler of the horizontal, return, fire-tube type. The arrangement of boilers is as follows: One donkey boiler on the upper deck in the boiler hatch; main boilers placed in a fore-and-aft direction in two compartments; with all fire rooms athwartship; in the after boiler compartment two single-ended and three double-ended boilers, and in the forward boiler compartment three double-ended boilers. All these boilers are of Scotch type, and the steam pressure is 200 pounds in donkey boiler as well as in main boilers. The diameter of single-ended and double-ended boilers is also the same, 16 feet. The two single-ended boilers will have four furnaces, with 76.58 square feet of grate surface and 3,208 square feet of heating surface. The six double-ended boilers will have eight furnaces with 153.16 feet of grate surface and 6,416 square feet of heating surface.

Sierra.—The steamship *Sierra*, recently built by the William

Cramp & Sons Ship and Engine Building Co., Philadelphia, for the Oceanic Steamship Co.'s service, finished her maiden trip from New York to San Francisco only a short time ago. It is worthy of note that in doing so she broke all previous records by seven days. Her sister ships are the *Sonoma* and *Ventura*. These vessels are under contract with the United States Government to maintain a fast mail service every three weeks from San Francisco to Auckland and Sydney, via. Honolulu and Samoan Islands. This new service will shorten the time between the terminals, San Francisco and Sydney, from twenty-five days, the time of the run heretofore, to twenty days. The dimensions of the vessels are: Length, 425 feet; beam, 50 feet; tonnage, 6,000; horsepower, 8,000. The new vessels have double bottoms, watertight compartments, two sets of triple-expansion engines and twin screws that will drive them at over 17 knots an hour. There are no steamers at present in the Pacific trade that compare with these fast vessels. There are accommodations for 240 first-class passengers, 100 second-class passengers and 100 steerage, and in each class nothing has been left undone that will tend to the safety and comfort of travelers. The ships are built to comply with navy regulations, and can be turned into auxiliary cruisers inside of thirty-six hours.—"Marine Review."

W. S. Grattan.—The new Buffalo fire boat brought up from the coast, and named the *W. S. Grattan*, is probably the most modern and best equipped fire boat ever built. She is 118 feet long, 23 feet beam and has a draught of 11 feet. Her pumping engines, consisting of three double ones, were made by the American Fire Engine Co., of Seneca Falls, N. Y., and gave the boat a guaranteed capacity of 9,000 gallons per minute. Under increased pressure it is claimed that 11,500 gallons per minute can be pumped. The *Grattan* has three stand-pipes, two in the bow and one aft. They are adjustable and can be fitted with nozzles ranging from three to five inches in diameter. In addition to this there are attachments for eighteen lines of hose.

YACHTS.

The Boston Defender.—The dimensions of the Lawson boat, furnished by Designer Crowninshield, are: Length over all, 140 feet 10½ inches; length on water line, 90 feet; overhang, forward, 27 feet 5 inches; overhang, aft, 23 feet 5 inches; beam, extreme, 23 feet 11½ inches; beam at water line, 23 feet 5 inches; draught, extreme, 20 feet; freeboard at stem head, 6 feet 11 inches; freeboard, least, 4 feet; freeboard at stern, 4 feet 8 inches; beam at forward end water line, 15 feet; beam at after end water line, 18 feet 9 inches; beam at stern, 11 feet 8 inches; center lateral plane aft load water line, 51 feet 5 inches; center of buoyancy aft load water line, 47.25 per cent.; area lateral plane, 772.6 square feet; area midship section, 117.9 square feet; area load-water line plane, 1,771.5 square feet; wetted surface, 2,913.5 square feet.

Alvina.—The twin-screw steam yacht *Alvina* was launched from the yard of Harlan & Hollingsworth, Wilmington, Del., on the morning of January 19. She was christened by Miss Harriett Mary Fletcher, a granddaughter of the owner of the yacht, Charles Fletcher. The *Alvina* is of these dimensions: Length along rail line, 212 feet; length on load-water line, 176 feet; beam, molded, 25 feet 11½ inches. She will be fitted with triple-expansion engines with cylinders 12 inches, 21½ inches and 25 inches, and 22 inches stroke. Steam will be supplied by two Scotch boilers, 13 feet diameter by 10 feet 6 inches. The yacht will be equipped with all modern conveniences. In construction she is fitted with a clipper stem and square stern, with one continuous deck house. There is a forecastle deck with crew's galley, lamp room, laundry, crew's mess, firemen's quarters, and a steam windlass on the forward end of the main deck. Abreast part of the deck house there is a bridge extending to the side of the vessel. There is a chart house and

captain's state room above the main house. The accommodations for the crew and officers are forward on cabin deck. The accommodations for owner are forward and aft of cabin deck. In the forward end of the house is situated the dining room. In the after part of the house is the library and state room. The *Alvina* will be rated at 100 A Lloyd's, and will have a speed of 14 knots.

Arrow.—Charles R. Flint's experimental steam yacht *Arrow*, which is designed to beat the Parsons turbine boats of England, is lying at a wharf in the Passaic awaiting her boilers from the Crescent shipyard at Elizabethport, and her engines from Lysander Wright's machine shop in Newark. The boat is of novel construction and designed to carry the highest power with the lightest weight, and it embodies many novel features in every part.

One of the lesser features, and one possessing the element of novelty, is the use of hydraulic thrust bearings. The thrust bearings are kept apart by a film of oil or other liquid under high pressure from hydraulic pumps, operated by the rotation of the shafts upon which the bearings work.

The two boilers are of the curved water-tube type, placed fore and aft, and fed from between them, having an inspection certificate for 440 pounds to the square inch and a capacity to supply 4,000 horsepower to the main engines and steam besides for pumps and auxiliary engines for lighting and other purposes. The main engines are quadruples, with cylinders 11, 17, 24 and 32 inches in diameter and ingenious reheating system of copper tubing between each cylinder. All of the parts of the engines which admit of the practice have been bored out to the last degree consistent with strength, this principle having been applied to both the frame and working parts.

The speed expected is 45 knots an hour. Aluminum reinforced with steel is used wherever possible, and every ounce is saved by the use of aluminum in internal fittings, including galley furniture. The hull of the vessel is constructed of two thicknesses of light mahogany with painted canvas between the layers, and the paint used is supposed not to dry out.

The length of the *Arrow* is 130 feet 4 inches over all and only four inches less on the water line. Her beam measurement is 12½ feet and her extreme draught will be about 4 feet 7 inches. The displacement will be about 68 tons under normal draught.—"Marine Record."

Margarita.—On 13th November this twin-screw steam yacht, built from the designs of Mr. G. L. Watson to the order of Mr. Drexel, the American millionaire, left the Tail-of-the-Bank at Greenock, for the purpose of undergoing her steam trials. On the way down the firth the vessel had to contend with a strong head wind. The trial consisted of six runs between the Cloch and the Cumbraes, and the mean speed attained over the full distance was 17¼ knots. To all concerned the trial was most satisfactory. Mr. Drexel expressed himself as being highly satisfied with the performance of his yacht. The *Margarita*, which has been in course of construction during the past eighteen months, has been built and engined by Messrs. Scott & Co., Greenock, and is of 1850 tons, with triple-expansion engines of 5,000 indicated horsepower. She is a finely-modeled vessel, and is equipped and furnished in a most luxurious and expensive manner.

Prinzessin Victoria Luise.—On the yard of Messrs. Blohm & Voss, at Hamburg, a twin-screw pleasure yacht has been built for the Hamburg-American Line, which stands prominent by her size for that type of ship and the elegance of her outfit.

She is destined by her owners to visit with first-class passengers exclusively, the most beautiful and interesting ports, and to make a trip round the world occasionally.

Her dimensions are: length over all, 446 feet (136 meters); length in water line, 400 feet (122 meters); breadth, 47 feet (14.33 meters); depth, 29.75 feet (9.07 meters); speed, 16 knots.

Ship.—Classification, German-Lloyd, highest class; material, mild Siemens-Martin steel; watertight bulkheads, 8; number of decks, 3; number of boats, 6; number of motor launches, 2; number of passengers, 200; chambres de luxe, 22; cabins for one person, 49; cabins for two persons, 52; cabins for servants, 3; dining saloon, to seat 200 persons; conversation saloon; reading

and writing saloon; smoking saloon; gymnasium; provision rooms cooled by refrigerating machine; number of crew, 160.

Engines.—Two quadruple expansion engines with four cranks each, indicating 4,000 horsepower in all; high-pressure cylinder, $19\frac{1}{16}$ inches=485 mm. diameter; 1st intermediate-pressure cylinder, $27\frac{9}{16}$ inches=700 mm. diameter; 2d intermediate-pressure cylinder, $39\frac{3}{8}$ inches=1,000 mm. diameter; low-pressure cylinder, $57\frac{1}{16}$ inches=1,450 mm. diameter; stroke, $36\frac{1}{4}$ inches=920 mm.; revolutions per minute, 120; number of boilers, 4; heating surface, 9,687.8 square feet=900 square meters; grate area, 239.36 square feet=21.4 square meters; boiler pressure, 215 pounds to the square inch, with Howden's forced draft; number of dynamos, 3; number of incandescent lamps, 1,060; capacity of bunkers, 1,250 tons.

OBITUARY.

LIEUTENANT CHARLES A. E. KING, U. S. NAVY.

In the death of Lieutenant Charles A. E. King, who died at sea on December 25, 1900, the service loses a bright and valuable officer and the Society an active and useful member, whose death will be mourned by many.

Lieutenant King was born in Baltimore, Md., August 7, 1858. He entered the Naval Academy as a Cadet Engineer September 14, 1876, graduating in June, 1880. He served on the *Monocacy* and *Swatara* on the Asiatic Station from 1880 to 1883, was commissioned Assistant Engineer in 1882, served on the *Brooklyn* on the North Atlantic and Asiatic Stations '85—'88, inspector of machinery at Columbian Iron Works, Baltimore, from '89 to '93, was commissioned Passed Assistant Engineer in 1893. Served on the U. S. S. *Newark* on the South Atlantic Station from '93 to '96, and was on duty as Assistant to the Chief of the Bureau of Steam Engineering during the late Spanish war. He was commissioned a Lieutenant in the line of the Navy March 3, 1899. He was ordered to duty on the Asiastic Station in December, 1899, but was found to be suffering with Bright's disease and given three months' sick leave. Upon the expiration of this leave he was ordered to the U. S. S. *Buffalo*, but upon the representation of the condition of his health to the Department he was transferred to the battleship *Indiana* on the home station, and the excellent condition of the machinery of that vessel when she was suddenly ordered into commission was largely due to his care and ability. In November, 1900, the *Indiana* was placed in reserve and Lieutenant King was ordered to duty on the Asiatic Station, via the U. S. S. *Solace*, and died on board that vessel at sea, near Hong Kong, China, of the disease from which he had been so long suffering. His dignified though cheerful and kindly disposition

made him respected and beloved by all who knew him. He leaves a widow, a daughter of the late James Broumel, of Baltimore, and two children.

WILLIAM HENRY HARRIS, COMMODORE, U. S. NAVY (Retired).

Commodore Harris was born in Massachusetts and was throughout his life a resident of that State. He was appointed Third Assistant Engineer in the Navy in 1861, promoted to Second Assistant Engineer in 1863, First Assistant Engineer in 1865, and Chief Engineer in 1883.

He was made a Captain in the line of the Navy by the operation of the Personnel Act, in March, 1899, and retired voluntarily under the provisions of that Act, with the rank of Commodore, in June, 1900. During his long service in the Navy he served on every station, beginning with war service in the Gulf Squadron, on the gunboat *Sagamore*, and ending his sea service on the cruiser *San Francisco*, in 1898. His services on shore comprised duty at the Naval Academy, Navy Yard, Boston, Mass., Bureau of Steam Engineering, Naval Examining Board for Engineers, and much special duty of importance. His last duty was an Inspector of Machinery building at the Bath Iron Works, Maine.

In all positions in life, both naval and private, his universal courtesy and pleasant manners endeared him to all with whom he came into contact, and his death, which occurred in Boston, on January 5, 1901, will be regretted by a host of friends.

REAR ADMIRAL PETER A. REARICK, U. S. NAVY (Retired).

Rear Admiral Rearick died at his home in Washington, D. C., on January 9, 1901. He was a native of Maryland and appointed from that State as Third Assistant Engineer in the Navy in 1860. He served during the civil war on the steamers *Crusader*, *Housatonic*, *Britannia* and monitor *Dictator*, serving continuously at sea during the whole period of that war. He

was promoted to Second Assistant Engineer in 1863, First Assistant Engineer in 1864, and Chief Engineer in 1874; he became a Captain in March, 1899, and retired in February, 1900, as a Rear Admiral. In his sea service of twenty-one years he served on many vessels, ending with the battleship *Indiana* in 1895. On shore he held many posts of importance—special duty in Washington, inspector of machinery of several of the vessels of the new Navy, member of the Steel Inspection Board, and at the various navy yards, being among them.

His death will be regretted by all who knew him, as he was universally loved and respected.

CHIEF ENGINEER ALEXANDER HENDERSON, COMMODORE U. S. NAVY (Retired).

Commodore Henderson, who died in New York city, on January 12, 1901, was born in Washington, D.C., July 12, 1832. He was the son of Thomas Henderson, late Colonel, U. S. A.; and the grandson of Thomas Truxtun, late Commodore, U. S. N. One of his brothers was an army officer, another was a naval officer, and two of his sisters married naval officers. He was therefore connected by family as well as by social ties to both services.

Shortly after entering the service in 1851, as a Third Assistant Engineer, he was assigned to the expedition which visited Asia in 1852–55, and which, under the command of Commodore M. C. Perry, opened up Japan to intercourse with Western civilization. In 1861, though a Virginian, he volunteered for active duty, and served the Union with distinction throughout the entire civil war. In after years he was Fleet Engineer of the Asiatic and European stations. In 1882, he was made the engineering head of the Naval Advisory Board, and the machinery of the first vessels of the new Navy were in great part designed and built under his direction. At different periods he was Chief Engineer of the New York, Boston and Washington Navy Yards. When the Spanish war broke out, although on the retired list, he volun-

teered his services for the war. He was sent to active duty, serving for several months as Fleet Engineer of the auxiliary naval force.

Commodore Henderson was a man of marked executive ability. He was quick in decision, ready in resource, and had a thorough knowledge of the principles of his profession. He possessed great business tact, and his judgment was respected by all his official superiors. As he attained high rank at an early age, he possessed a commanding influence at the Navy Department for a long term of years.

CHIEF ENGINEER B. B. H. WHARTON, CAPTAIN, U. S. NAVY (Retired).

Captain B. B. H. Wharton was born in Virginia in 1833. He entered the Navy as Third Assistant Engineer in 1857, and for a period of forty years served on the active list.

He was a man of unblemished character; of high professional attainments, and exceedingly beloved throughout the service. During his long and honorable career he was assigned to much responsible and important duty. Without being a specialist he had rare engineering ability, and therefore rendered valuable assistance in the solution of the far-reaching questions concerning the rehabilitation of the Navy that were submitted to the Boards of which he was a member.

During his connection with the Navy his work was of a varied character. He served as Fleet Engineer; as Chief Engineer of Navy Yards; as senior member of Trial Boards; as member of numerous special Boards that were appointed to advise the Department, and as President of the Board of Examining Engineers.

Although on the retired list at the breaking out of the Spanish-American war, he volunteered for active service and was assigned special work under the Navy Department.

He was of exceedingly retiring disposition, and never sought particular duty. Having confidence in the fairness and judgment of those entrusted with responsibility, he cheerfully ac-

cepted every detail that was assigned him. His integrity and conscientious performance of duty were of such nature that his professional opinions and recommendations always had great weight with his superiors. His consideration and thoughtfulness for his junior associates endeared him to the younger officers; and in his death, which occurred on January 13, 1901, there passed from the service a man who upheld throughout his life the honor, prestige and best traditions of the Navy.

ASSOCIATION NOTES.

ANNUAL MEETING.—The regular meeting of this Society was held at the Navy Department on the evening of January 7, 1901. The meeting was called to order at 7·30 P. M., with Commander Webster, U. S. N., the President, in the chair.

The report of the Secretary-Treasurer was read regarding the financial condition of the Society during the past year, and was as follows:

GENTLEMEN: The financial condition of the Society is excellent, and the year just ended has been a prosperous one. There has been but a slight change in membership and a considerably increased interest shown in the advertising feature. The number of members and associate members is now 478, exclusive of 12 honorary members and prize essayists, while there is, in addition, a subscription list of about 60 names.

The following is the statement of receipts and expenditures for 1900:

RECEIPTS.

Balance on hand January 7, 1900	$4,430.30
Annual dues	2,244.96
Subscriptions, sales of JOURNALS, etc	681.75
Sale of Society buttons	1.50
Advertisements	1,996.07
Interest on deposit	79.98
Total	$9,434.56

EXPENDITURES.

Printing JOURNAL, reprints, etc	$2,726.24
Printing list, index, circulars, etc	125.01
Illustrations	359.93
Prize essays and medal	130.00
Advertising work, commissions, etc	150.61
Incidentals, postage, etc	55.84
Salary Secretary-Treasurer to 7th	917.50
Total	$4,465.13
Balance in bank	4,969.43
Total	$9,434.56

The accounts have been audited by a committee in accordance with the By-Laws and found to be correct.

Respectfully submitted,

A. B. WILLITS, *Secretary-Treasurer.*

The counting of the votes for officers for 1901 and announcement of the result was the next order of business, and resulted as follows:

OFFICERS ELECTED FOR 1901.

President, Commander Charles W. Rae, U. S. N.

Secretary-Treasurer, Lieutenant B. C. Bryan, U. S. N.

Council.—Lieutenant Commander James H. Perry, U. S. N.; Lieutenant Commander W. R. Worthington, U. S. N.; Lieutenant R. S. Griffin, U. S. N.

The vote for prize essay for 1900 resulted in the award being made to Lieutenant Commander W. R. Worthington, U. S. N., for his article on "Corrosion of Boiler Tubes in the U. S. Navy" (No. 3, page 587, and No. 4, page 907).

A vote of thanks was extended to the retiring President and Secretary-Treasurer for the efficient manner in which they had conducted the duties of their offices, and after some general discussion on minor matters of importance the meeting adjourned.